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(54) **THERMAL MASS FLOW CONTROLLER HAVING ORTHOGONAL THERMAL MASS FLOW SENSOR**

THERMISCHER MASSENDURCHFLUSSREGLER MIT SENKRECHT ANGEORDNETEM MASSENDURCHFLUSSSENSOR

RéGULATEUR THERMIQUE DE DéBIT MASSIQUE UTILISANT UN CAPTEUR THERMIQUE DE DéBIT MASSIQUE DISPOSé PERPENDICULAIREMENT

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(73) Proprietor: **UNIT INSTRUMENTS, INC.**
Yorba Linda, CA 92687 (US)

(72) Inventors:
- **DOYLE, James, Holohan**
  Orange, CA 92667 (US)
- **DOYLE, Michael, John**
  Villa Park, CA 92667 (US)
- **LEMAY, Dan, Browne**
  Fallbrook, CA 92028 (US)
- **VU, Kim, Ngoc**
  Yorba Linda, CA 92686 (US)

(74) Representative:
McLeish, Nicholas Alistair Maxwell et al
Boult Wade Tennant
27 Furnival Street
London EC4A 1PQ (GB)

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Description

BACKGROUND OF THE INVENTION

[0001] The invention relates generally to a thermal mass flow meter and in particular relates to a thermal mass flow meter having a portion of a sensing element oriented transversely with respect to a bypass flow path extending through the thermal mass flow meter. The invention also relates to a thermal mass flow controller incorporating a thermal mass flow meter.

[0002] Thermal mass flow controllers and thermal mass flow meters are employed in the semiconductor industry and in other industries for measuring the rate of flow of a quantity of gas employed in a piece of equipment for the manufacture of a semiconductor wafer and the like. Such thermal mass flow controllers are often used in gas shelves of diffusion furnaces, chemical vapor deposition systems, plasma etching systems, sputtering systems and the like to meter precisely the amounts of reactant and carrier gases to be delivered to a treatment chamber of the equipment. Such treatment chambers may comprise process tubes or process chambers. Such gases may include hydrogen, oxygen, nitrogen, argon, silane, dichlorosilane, ammonia, phosphorus oxychloride, diborane, boron tribromide, arsine, phosphine, sulfur hexafluoride and the like. Oftentimes, multiple gas sources are employed in conjunction with a particular treatment chamber. For instance, silane may be used in the treatment chamber for chemical vapor deposition of polycrystalline silicon, also known as polysilicon, in combination with one or more doping agents. As a result, each of the process tubes or process chambers in a particular piece of equipment may have multiple reactant gas delivery lines connected and must, of necessity, have multiple mass flow controllers connected in the gas lines to meter appropriate amounts of the reactant and carrier gases process gases to the treatment chamber. The use of such multiple mass flow controllers, of course, expands the size of the gas shelves used for these types of equipment.

[0003] The manufacture of modern semiconductors having finer and finer microelectronic features has necessitated that the acceptable contamination levels within clean rooms in which such manufacturing takes place have continuously been reduced in order to provide adequate wafer yields. As a result, the expense involved in the construction of such clean rooms has steadily increased and is anticipated to continue increasing. As such clean rooms are expanded in size due to the relative amount of floor space or footprints occupied by equipment, their corresponding cost of course also increases. Thus, the equipment size for a given throughput through a particular clean room is an economic consideration which is always of importance to a wafer fabricator. A mass flow controller capable of increasing the flow rate by a factor of two without changing the size between joints of an existing mass flow controller is described in US-A-5,080,131.

[0004] Concomitant with the space requirements for clean rooms is a requirement that footprint considerations often require that mass flow controllers be capable of use in a variety of orientations. Unfortunately, in most cases, conventional thermal mass flow controllers may only be used with their bypass and sensors both positioned substantially horizontally to avoid introducing unwanted convective effects into the sensor which would result in perturbation of the mass flow controller readings.

[0005] One approach to solving the convection problem is to allow a flow controller for instance to be oriented vertically, as set forth in WO-A-9119959. The thermal mass flow meter has a sensor which allows the bypass flow path to be oriented in a substantially vertical direction without the necessity of the sensor tube being oriented in a substantially vertical direction. The mass flow controller, however, like other prior art mass flow controllers may only be used in a vertically oriented direction. That is, it has a single preferred direction in which it may be oriented. It may not be used in a variety of attitudes other than with the bypass position substantially vertically.

[0006] Another approach is described in US-A-4,100,801 in which the sensor includes a loop in the shape of a single-turn helix. Circulation of the flow through the loop cancels gravity-induced convection forces caused by temperature gradients and significantly reduces sensitivity to changes in attitude.

[0007] U.S. Patent No. 4,776,213 to Blechinger et al discloses a mass airflow meter in a bypass which is transverse to the main air flow path.

[0008] What is needed then is a thermal mass flow controller which is compact and may be positioned in a variety of orientations without introducing convective perturbations in the flow controller reading.

SUMMARY OF THE INVENTION

[0009] According to a first aspect of the present invention there is provided a thermal mass flow meter for measuring a rate of flow of a gas or vapor, comprising:

a base having a sensor receiving wall, an inlet for receiving the flow of gas whose mass rate of flow is to be measured, and a primary flow path operatively connected with said inlet to provide a pressure drop to the flowing gas, said primary flow path extending in a primary flow path direction;
a thermal sensor mounted on said sensor receiving wall and having a sensor tube, a first portion of the sensor tube being connected to an upstream side of the primary flow path, a second portion of the sensor tube being connected to a downstream portion of the primary flow path, and a flow measuring portion of the sensor tube extending between said first and second tube portions and having a thermally

responsive means in good thermal connection therewith; and

an outlet connected to said primary flow path to receive said flow of gas, characterised in that the flow measuring portion of the sensor tube is arranged to extend both substantially transversely to the primary flow path direction and substantially parallel to the sensor receiving wall such that the flow measuring portion of the sensor tube is maintained substantially horizontal when the primary flow path direction is substantially horizontal, substantially vertical or anywhere in between.

[0010] Thus the present invention provides a thermal mass flow meter which may be operated in a variety of orientations without convectively perturbing the response of the flow meter.

[0011] The present invention also provides a thermal mass flow meter which is compact through the use of a sensor having a flow measuring portion oriented substantially orthogonally or transversely with respect to a primary gas flow path to which it is connected.

[0012] The present invention still further provides a thermal mass flow meter or a thermal mass flow controller having a relatively small footprint.

[0013] Other aspects and advantages of the present invention will be obvious to one of ordinary skill in the art upon a perusal of the following specification and claims in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

FIG. 1 is a perspective view of a thermal mass flow controller having an orthogonal thermal mass flow controller comprising a sensor unit and a valve unit with a normally open valve and an electronics package for connection to the sensor unit and valve;

FIG. 2 is an elevational view of the thermal mass flow controller shown in FIG. 1, having portions broken away, to show details of the orientation of a thermal mass flow sensor therein with respect to a primary fluid flow path through a sensor unit base;

FIG. 3 is a sectional view taken substantially along line 3--3 of FIG. 2;

FIG. 4 is a sectional view taken substantially along line 4--4 of FIG. 3;

FIG. 5 is a perspective view of a second embodiment of the thermal mass flow controller orthogonal sensor thermal mass flow controller having a normally closed valve;

FIG. 6 is an elevational view of the thermal mass flow controller shown in FIG. 5, having portions broken away, to show details of the orthogonal orientation of a thermal mass flow sensor with respect to a primary fluid flow path through a sensor unit base;

FIG. 7 is a sectional view taken substantially along line 7--7 of FIG. 6;

FIG. 8 is a block diagram of the electronics package shown in FIGS. 1 and 5 showing its electrical connection to the sensor unit and the valve unit;

FIG. 9 is a schematic diagram of a constant current source and sensor preamplifier of block diagram shown in FIG. 8;

FIG. 10 is a schematic diagram of a sensor tuning circuit shown in FIG. 8;

FIG. 11 is a schematic diagram of a linearizer circuit shown in FIG. 8;

FIG. 12 is a schematic diagram of an auto-zero circuit shown in FIG. 8;

FIG. 13 is a schematic diagram of the input buffer, post filter, soft start circuit shown in FIG. 8;

FIG. 14 is a schematic diagram of a normally-open valve driver circuit shown in FIG. 8;

FIG. 15 is a block diagram of a normally-closed valve driver circuit shown in FIG. 8;

FIG. 16 is a sectional view of an alternative embodiment of the present invention; and

FIGS. 17A-C are schematic diagrams of a circuit of the alternative embodiment shown in FIG. 16.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] A thermal mass flow controller having an orthogonal thermal mass flow sensor and embodying the present invention is shown in FIGS. 1, 2, 3, 4 and 8 and is generally referred to by reference numeral 10. The thermal mass flow controller 10 comprises a thermal mass flow meter 12 having a sensor unit 14 and an electronics package 16 connected to the sensor unit 14. A flow of gas through the sensor unit 14 produces a mass flow rate signal. The electronics package produces a valve command signal in response to the mass flow rate signal. A valve unit 18 is connected to the sensor unit 14 to receive a flow of gas and to the electronics package 16 to receive the valve command signal. The sensor unit 14 has a base 20 with an orthogonal or transverse thermal mass flow sensor 22 connected to it.

[0016] The base 20 is comprised of metal having a substantially rectangular prismatic shape. The base 20 includes a bottom wall 24, a pair of lateral side walls 26 and 28, a top wall 30, an inlet wall 32 and an outlet wall 34. An inlet opening 36 is formed in the inlet face 32. An outlet 38 is formed in the outlet face 34. The base block defines a substantially circular cylindrical primary fluid or gas flow path 40 therein extending from the inlet 36 to the outlet 38. A pressure dropping bypass 42 comprising a plurality of elongated small diameter tubes is packed within the primary fluid flow path 40 and defines an upstream portion 44 of the primary fluid flow path 40 and a downstream portion 46.

[0017] An inlet sensor flow path 50 connects the inlet 36 to the orthogonal thermal mass flow sensor 22. An outlet flow path 52 connects the outlet side of the or-

thogonal thermal mass flow sensor to the outlet 38. An inlet connector 56 is connected by a plurality of threaded fasteners 58 to the base block 20. A metal gasket or seal 60 is positioned between the inlet 56 and the base block 20 to provide a sealing connection therewith.

[0018] The thermal mass flow sensor 22 includes a thermal mass flow sensor base 70 to which is connected an inlet leg 72. The sensor tube 71 includes the inlet tube leg 72, a flow measuring tube portion or leg 76 and an outlet tube leg 78. The flow measuring portion 76 of the sensor 22 includes a pair of series connected electrical resistance windings 84 and 86 wound thereabout. The inlet and outlet legs 72 and 78 are connected via a plurality of wire wrap heat sink connectors 90 to a printed circuit board 92 which provides support and a thermal shunt. A batting 100 surrounds the flow measuring portion 76 to prevent it from being disturbed thermally. A covering can 102 encloses the flow measuring portion 76 including the windings 84 and 86. Multiple lead connectors 106 lead from the orthogonal thermal mass flow sensor 22 to an electrical connector 108 which is connected to the electronics package 16.

[0019] The orthogonal thermal mass flow sensor 22, it should be appreciated, has its sensor measuring portion 76 arranged externally of and transversely or orthogonally with respect to the primary fluid flow path 40. This allows the primary fluid flow path 40 to be oriented both horizontally. vertically or anywhere in between while maintaining the flow measuring portion 76 horizontal to prevent convective effects from perturbing the response of the flow measuring portion 76. In addition, the transverse orientation of the thermal mass flow sensor 22 with respect to the primary fluid flow path 40 allows a very compact thermal mass flow meter 12 to be achieved.

[0020] The valve unit 18 includes a normally open electromagnetic valve 110 having a solenoid 112 for driving a valve pintle 114 with respect to a valve seat 116. The valve seat 116 is connected to a valve block 118 having a valve inlet bore 120 in communication with the valve seat 116 and a valve outlet bore 122. The valve block 118 includes an outlet face 124 to which is connected an outlet 126. A plurality of threaded fasteners 128 hold the outlet 126 in contact with a metal seal 130 which is positioned between the outlet 126 and the wall 124.

[0021] Referring now to FIG. 8, the electronics package 16 shown in FIG. 5 is shown therein and includes a constant current source 160 for energizing temperature dependent resistance windings 84 and 86. A sensor tuning circuit 162 biases the current to windings 84 and 86 in order to speed up performance. A preamplifier 164 receives along an output line 106 the signal from the voltage divider 84, 86 and amplifier and feeds it via a line 214 to the sensor tuning circuit output 162. A linearizer 166 is connected to the sensor tuning circuit 162 and is driven thereby and provides piecewise linearization to the output mass flow signal. A set point buffer 170 is connected to receive a set point signal on a line 172 and feeds the set point signal through a soft start circuit 174 to the valve driver 168 where the set point signal is compared to the mass flow rate signal to generate a valve error or valve control signal on a line 176. The valve error or valve control signal is fed to the valve 110 or, as will be seen hereinafter, the valve 610 to control the amount of valve opening. The linearizer circuit 166 also supplies an output mass flow rate signal via a line 167 to the post filter 180 which provides a filtered signal on a line 184 as output of the meter.

[0022] Referring now to FIG. 9, a constant current source 160 is shown therein and includes an amplifier 200 connected to a transistor 202 having an AC ground capacitor 204. The lead 106 is connected to the ground capacitor 204 and a transistor 202, and energizes the sensor windings 84 and 86.

[0023] Referring now to the sensor tuning circuit 162 shown in FIGS. 9 and 10, it will be apparent that the output from the sensor on line 106 is fed through resistors to a compensation resistor 212 which is received by an amplifier 220, which is a portion of the preamplifier 164. The output signal of the amplifier 220 is fed to the line 214 which is connected to an amplifier 210 of the sensor tuning circuit 162 causing the sensor tuning circuit 162 to speed up the electrical response of the sensor windings 84 and 86.

[0024] The sensor tuning circuit 162 supplies an output signal on a line 230 to the linearizer 166. The linearizer 166, as may best be seen in FIG. 11, receives the raw mass flow signal at a line 230, which signal is fed through a variable resistor 244 to an amplifier 232. The amplified signal is fed to a second amplifier 234, which provides an output signal via line 167. The output signal is also fed through a plurality of precision segment generators 236, 238 and 240, which provide precision segment generation at the 25%, 50% and 75% point flow rates. The output of the linear segment generators is fed back via line 242 to the input of the amplifier 232. As shown in FIG. 14, the linearized signal is fed via the line 167 to the normally open valve driver circuit 168. The mass flow signal is fed to a comparator 260 which also receives an input signal from a lead 262 connected to the soft start circuit 174 as shown in FIG. 8. The buffered set point signal is compared to the mass flow signal in the amplifier 260, and a valve control error signal is produced on a line 266, which is fed to a valve control transistor 268. The valve control transistor 268 is connected via lead 270 to a Darlington pair 272 with drive leads 274 and 276, respectively. Line 276 is connected to the solenoid of coil 112 of the valve 110. Coil 112 is also connected to a feedback lead 278 which provides a feedback signal to a feedback amplifier 280, which is connected through a resistor 282 to the base of the transistor 268. It may also be appreciated that a low set point speed up circuit 286 is provided which receives the set point signal from the line 267, feeds it to a speed up amplifier 288, which provides a speed up output signal

to the transistor 268.

[0025] Referring now to FIG. 13, the post filter 180 is shown therein including a postfilter amplifier 300 which receives the linearized mass flow signal from a line 167 after having been fed through a resistance network, and produces a filter output signal with most of the artifacts and high frequency noise removed at the lead 184 for use via a direct digital controller or other device which is connected to the mass flow controller to determine the instantaneous flow rate through the flow controller. Furthermore, the soft start circuit 174 is driven from the output of the input buffer 170 by receiving the buffered set point signal at an amplifier 310 connected to a linear capacitor charging network 312, which feeds a current needed to provide a linear voltage charging ramp to a capacitor 314. Capacitor 314 is charged by the ramp voltage in a linear fashion to drive an amplifier 320, which provides a linearly ramped output signal on a lead 322. The ramped output signal for use in soft start, is provided via the lead 322 through a resistor 324, as shown in FIG. 9, to a lead 326, which is connected via a resistor 328 as shown in FIG. 14, to the input of the comparator 260 of the valve driver circuit.

[0026] A second embodiment of the present invention is a thermal mass flow controller having an orthogonal thermal mass flow sensor shown in FIGS. 5, 6, 7 and 8 and generally referred to by reference numeral 510. The thermal mass flow controller 510 comprises a thermal mass flow meter 512 having a sensor unit 14 identical to the sensor unit 14 of the thermal mass flow controller 10 and an electronics package 16 connected to the sensor unit 14. A flow of gas through the sensor unit 14 produces a mass flow rate signal. The electronics package 16 produces a valve command signal in response to the mass flow rate signal. A valve unit 518 is connected to the sensor unit 14 to receive a flow of gas and to the electronics package 16 to receive the valve command signal.

[0027] The valve unit 518 includes a valve block 520 to which is attached a normally closed electromagnetic valve 610 having a solenoid 612 to drive a valve pintle 614 with respect to a valve seat 616. The valve seat 616 rests on a valve block 618 having a valve inlet bore 620 in communication with the valve seat 616 and a valve outlet bore 622. The valve block 516 includes an outlet face 624 to which is connected an outlet 626. A plurality of threaded fasteners 628 holds the outlet 626 in contact with a metal seal 630 which is positioned between the outlet 626 and the wall 624.

[0028] The valve driver circuit for the normally closed valve 610 is shown in FIG. 15. Similarly numbered elements in FIG. 15 perform the same functions as the corresponding elements shown in FIG. 14 and described above.

[0029] A third embodiment of the present invention comprises a thermal mass flow controller having an orthogonal thermal mass flow sensor as shown in FIGS. 16 and 17A through 17C. As generally referred to by reference numeral 710, the mass flow controller 710 comprises a thermal mass flow meter 712 having a sensor unit 714 and a circuit 716 connected to the sensor unit 714. A flow of gas through the sensor unit 714 produces a mass flow rate signal. The circuit 716 produces a valve command signal in response to the mass flow rate signal. A valve unit 718 is connected to the sensor unit 714 to receive a flow of gas and to the circuit 716 to receive the valve command signal. The sensor unit 714 has a base 720 with an orthogonal or transverse thermal mass flow sensor 722 connected to it. The base 720 is comprised of metal having a substantially rectangular configuration. The base 720 includes a bottom 724, a top wall 730, an inlet wall 732 and an outlet wall 734. An inlet opening 736 is formed in the inlet face 732. An outlet opening 738 is formed in the outlet face 734. The base block defines a substantially circular cylindrical fluid or gas flow path 40 therein extending from the inlet 736 to the outlet 738. A pressure dropping bypass 742 comprising a plurality of elongated small diameter tubes is packed within the primary fluid flow path 740 in a holder 743a which is mounted within a nickel ring 743b and defines an upstream portion 744 of the primary fluid flow path 740 and a downstream portion 746.

[0030] A short sensor flow path 750 connects the inlet 736 to the orthogonal thermal mass flow sensor 722. A short outlet sensor flow path 752 connects the outlet side of the orthogonal thermal mass flow sensor to the outlet 738. The inlet 750 and outlet 752 are adjacent the ring 741 to reduce conventional thermal siphoning which could perturb flow meter accuracy. An inlet connector 756 is connected to the base block 720. A metal gasket or seal 760 is positioned between the inlet 756 and the base block 720 to provide a sealing connection therewith.

[0031] The thermal mass flow sensor 722 includes a thermal mass flow sensor base 770 having a 316L stainless steel sensor tube 771. The sensor tube 771 is identical to the sensor tube and is U-shaped. The sensor tube 771 includes an inlet tube leg 772, a flow measuring tube portion or leg 776 and an outlet leg. The flow measuring portion 776 of the sensor 772 includes a pair of series connected electrical resistance windings 784 and 786 wound thereabout. The windings 784 and 786 are connected via leads 806 to the multiple printed circuit boards 806a, 806b and 806c positioned within a cover 806d. The windings 784 and 786 and the printed circuit boards 806a, 806b and 806c are part of the circuit 716. A batting 800 surrounds the flow measuring portion 776 to prevent it from being disturbed thermally. A covering can 802 encloses the flow measuring portion 776, including the windings 784 and 786.

[0032] The orthogonal thermal mass flow sensor 722, it should be appreciated, has its sensor measuring portion 776 arranged externally of and transversely or orthogonally with respect to the primary fluid flow path 740. This allows the primary fluid flow path 740 to be oriented both horizontally, vertically or anywhere in be-

tween, while maintaining the flow measuring portion 776 horizontal to prevent convective effects from perturbing the response of the flow measuring portion 776. The thermal mass flow sensor 722 may be removed for servicing without disturbing the bypass 742. Likewise, the bypass 742 may be changed without having to remove the sensor 722. Further, it should be appreciated that the close spacing together of the sensor inlet and sensor outlet portions further reduces convective effects which might perturb the response of the flow measuring portion 776. In addition, the transverse orientation of the thermal mass flow sensor 722, with respect to the primary fluid flow path 740, allows a very compact modular thermal mass flow meter 12 to be achieved.

[0033] The valve unit 714 includes a normally closed electromagnetic valve 810 having a solenoid 812 for driving a valve pintle 814 with respect to a valve seat 816. The valve seat 816 is connected to a valve block 818 having a valve inlet bore 820 in communication with the valve seat 816 and the valve outlet bore 822. The valve block 818 includes an outlet 826.

[0034] Referring now in particular to the electronic circuit 716 which is seen to be positioned within the housing, the electronic circuit 716 includes a constant current generator 910 which drives the sensor windings 784 and 786. A center tap 912 between the sensor windings 784 and 786 feeds a flow signal through one of the leads 806 to a differential amplifier 914 which amplifies the flow signal and sends it to a differential amplifier 916 for further amplification. The differential amplifier 916 also comprises a speed-up circuit to provide faster response. Further amplification takes in the differential amplifier circuit 920 which feeds an unlinearized flow signal on a line 921 through an amplifier 922 to a plurality of segment generators 924 for piecewise linearization of the unlinearized flow signal. The plurality of segment generators 924 are fed from a potential source 925a through a line 925b. A plurality of segment generators 924 include a first segment generator 926, a second segment generator 928, a third segment generator 930. The first segment generator 926 has a break point at the 25% flow rate. The second segment generator 928 breaks at the 50% flow rate. The segment generator 930 breaks at the 75% flow rate. The signals from the segment generators are fed back through the amplifier 922 which outputs a linearized flow signal. The linearized flow signal is fed through an amplifier 940 which through a line 941 drives an error amplifier 942. The error amplifier 942 receives a flow set point signal on a line 944 from an external source and the linearized flow signal on line 946 and provides a flow error signal output at an output 948. The flow error signal is then fed through a resistor 950 to a line 952 to drive a Darlington transistor pair 954 having transistors 956 and 958. The transistor 958 is coupled to the valve 810 to control the position of the valve pintle 814 in response thereto.

[0035] It may be appreciated that the instant inventive thermal mass flow controllers 10, 510 and 710, through the use of thermal mass flow sensors oriented transversely or orthogonally to the primary fluid flow paths, provide attitude insensitive mass flow sensors having very small footprints. This allows the mass flow controllers to be oriented in various positions in cramped gas shelves thereby occupying little space but without a degradation in performance.

[0036] It may be appreciated that while specific embodiments of the instant invention have been disclosed herein, the scope of the instant invention shall be limited only by the appended claims.

Claims

1. A thermal mass flow meter (12) for measuring a rate of flow of a gas or vapor, comprising:

    a base (20) having a sensor receiving wall (30), an inlet (36) for receiving the flow of gas whose mass rate of flow is to be measured, and a primary flow path (42) operatively connected with said inlet (36) to provide a pressure drop to the flowing gas, said primary flow path (42) extending in a primary flow path direction;
    a thermal sensor (22) mounted on said sensor receiving wall (30) and having a sensor tube (71), a first portion (72) of the sensor tube (71) being connected to an upstream side (44) of the primary flow path (42), a second portion (78) of the sensor tube (71) being connected to a downstream portion (46) of the primary flow path (42), and a flow measuring portion (76) of the sensor tube (71) extending between said first and second tube portions (72, 78) and having a thermally responsive means (84, 86) in good thermal connection therewith; and
    an outlet (38) connected to said primary flow path (42) to receive said flow of gas, characterised in that the flow measuring portion (76) of the sensor tube (71) is arranged to extend both substantially transversely to the primary flow path direction and substantially parallel to the sensor receiving wall (30) such that the flow measuring portion (76) of the sensor tube (71) is maintained substantially horizontal when the primary flow path direction is substantially horizontal, substantially vertical or anywhere in between.

2. A mass flow controller (10) for controlling a flow of a gas comprising a thermal mass flow meter (12) in accordance with claim 1 and a valve (18) connected to receive a signal representative of the flow sensed by the thermal sensor (22) and to control the rate of flow through the valve (18).

3. A thermal mass flow controller (10) for controlling a

flow of gas as defined in claim 2, wherein said first portion (72) of the sensor tube (71) is formed integrally with said flow measuring portion (76) and said second portion (78) of the sensor tube (71) is formed integrally with said flow measuring portion (76).

Patentansprüche

1. Thermischer Massendurchflußmesser (12) zum Messen einer Durchflußrate eines Gases oder Dampfs, umfassend:

   - eine Basis (20) mit einer Sensoraufnahmewand (30), einem Einlaß (36) zur Entgegennahme der Gasströmung, deren Massendurchflußrate zu messen ist, und einem primären Strömungsweg (42), welcher betriebsmäßig mit dem Einlaß (36) verbunden ist, um einen Druckabfall an dem strömenden Gas vorzusehen, wobei der primäre Strömungsweg (42) in einer Primärströmungswegrichtung verläuft,
   - einen thermischen Sensor (22), welcher an der Sensoraufnahmewand (30) angebracht ist und ein Sensorrohr (71) aufweist, wobei ein erster Abschnitt (72) des Sensorrohrs (71) mit einer stromaufwärtigen Seite (44) des primären Strömungswegs (42) verbunden ist, ein zweiter Abschnitt (78) des Sensorrohrs (71) mit einem stromabwärtigen Abschnitt (46) des primären Strömungswegs (42) verbunden ist und ein Durchflußmeßabschnitt (76) des Sensorrohrs (71) zwischen dem ersten und dem zweiten Rohrabschnitt (72, 78) verläuft und ein wärmeempfindliches Mittel (84, 86) in gutem thermischen Kontakt mit diesem aufweist, und
   - einen Auslaß (38), welcher mit dem primären Strömungsweg (42) verbunden ist, um die Gasströmung aufzunehmen,

   dadurch gekennzeichnet, daß der Durchflußmeßabschnitt (76) des Sensorrohrs (71) so angeordnet ist, daß er sich sowohl im wesentlichen quer zur Primärströmungswegrichtung als auch im wesentlichen parallel zur Sensoraufnahmewand (30) erstreckt, derart, daß der Durchflußmeßabschnitt (76) des Sensorrohrs (71) im wesentlichen horizontal gehalten ist, wenn die Primärströmungswegrichtung im wesentlichen horizontal, im wesentlichen vertikal oder irgendwo dazwischen liegt.

2. Massendurchflußregler (10) zum Regeln/Steuern einer Gasströmung, umfassend einen thermischen Massendurchflußmesser (12) nach Anspruch 1 und ein Ventil (18), welches so angeschlossen ist, daß es ein Signal erhält, welches für den von dem thermischen Sensor (22) erfaßten Durchfluß repräsentativ ist, und die Durchflußrate durch das Ventil (18) regelt/steuert.

3. Thermischer Massendurchflußregler (10) zum Regeln/Steuern einer Gasströmung nach Anspruch 2, bei dem der erste Abschnitt (72) des Sensorrohrs (71) integral mit dem Durchflußmeßabschnitt (76) ausgebildet ist und der zweite Abschnitt (78) des Sensorrohrs (71) integral mit dem Durchflußmeßabschnitt (76) ausgebildet ist.

Revendications

1. Débitmètre de masse thermique (12) pour mesurer un débit d'écoulement d'un gaz ou d'une vapeur, comprenant :

   une base (20) comportant une paroi de réception de détecteur (30), un orifice d'entrée (36) pour recevoir le flux de gaz dont le débit d'écoulement massique doit être mesuré, et un trajet d'écoulement principal (42) raccordé de façon opérationnelle audit orifice d'entrée (36) de façon à communiquer une chute de pression au gaz en écoulement, ledit trajet d'écoulement principal (42) s'étendant dans une direction de trajet d'écoulement principal ;
   un détecteur thermique (22) monté sur ladite paroi de réception de détecteur (30) et comportant un tube de détecteur (71), une première partie (72) du tube de détecteur (71) étant raccordée à un coté amont (44) du trajet d'écoulement principal (42), une deuxième partie (78) du tube de détecteur (71) étant raccordée à une partie aval (46) du trajet d'écoulement principal (42), et une partie de mesure d'écoulement (76) du tube de détecteur (71) s'étendant entre lesdites première et deuxième parties de tube (72, 78) et comportant des moyens thermiquement sensibles (84, 86) en bonne connexion thermique avec celles-ci ; et
   un orifice de sortie (38) raccordé audit trajet d'écoulement principal (42) pour recevoir ledit flux de gaz, caractérisé en ce que la partie de mesure d'écoulement (76) du tube de détecteur (71) est agencée de façon à s'étendre tout à la fois sensiblement transversalement par rapport à la direction du trajet d'écoulement principal et sensiblement parallèlement à la paroi de réception de détecteur (30), de telle sorte que la partie de mesure d'écoulement (76) du tube de détecteur (71) soit maintenue sensiblement horizontale lorsque la direction du trajet d'écoulement principal est sensiblement horizontale, sensiblement verticale ou dans toutes autres directions entre ces deux directions.

2. Dispositif de contrôle d'écoulement massique (10) pour contrôler l'écoulement d'un gaz comprenant un débitmètre de masse thermique (12) selon la revendication 1 et une vanne (18) connectée de façon à recevoir un signal représentatif de l'écoulement détecté par le détecteur thermique (22) et à contrôler le débit d'écoulement à travers la vanne (18).

3. Dispositif de contrôle d'écoulement de masse thermique (10) pour contrôler un écoulement de gaz selon la revendication 2, dans lequel ladite première partie (72) du tube de détecteur (71) est formée d'une seule pièce avec ladite partie de mesure d'écoulement (76) et ladite deuxième partie (78) du tube de détecteur (71) est formée d'une seule pièce avec ladite partie de mesure d'écoulement (76).

FIG.1

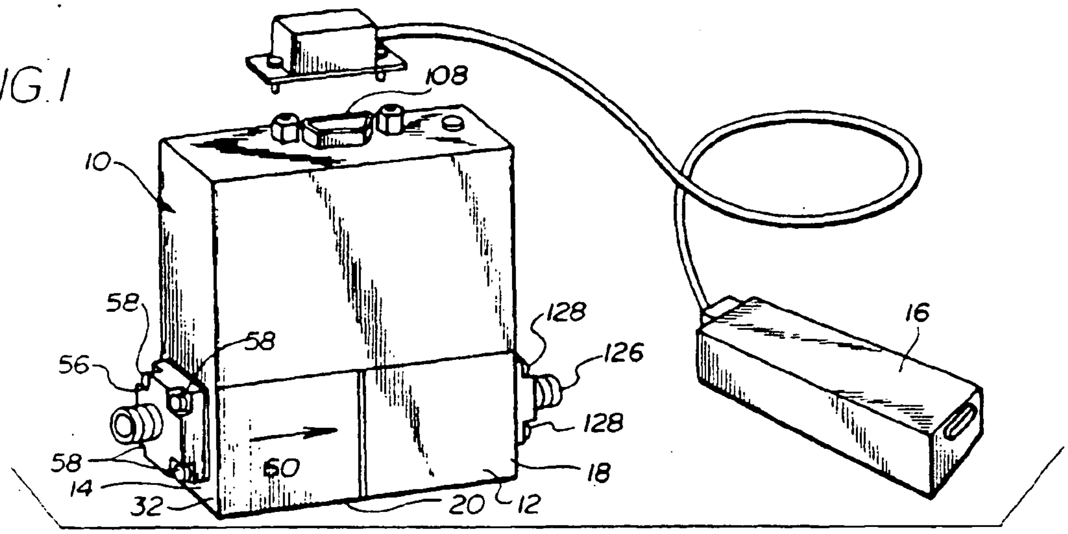
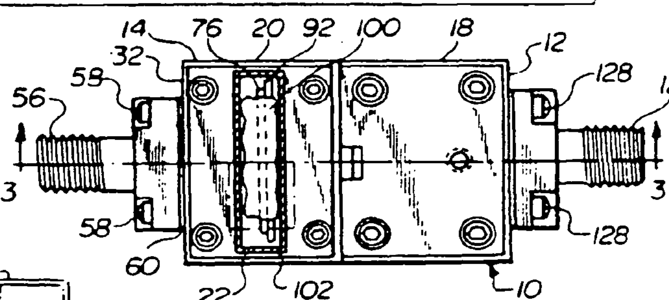


FIG.2



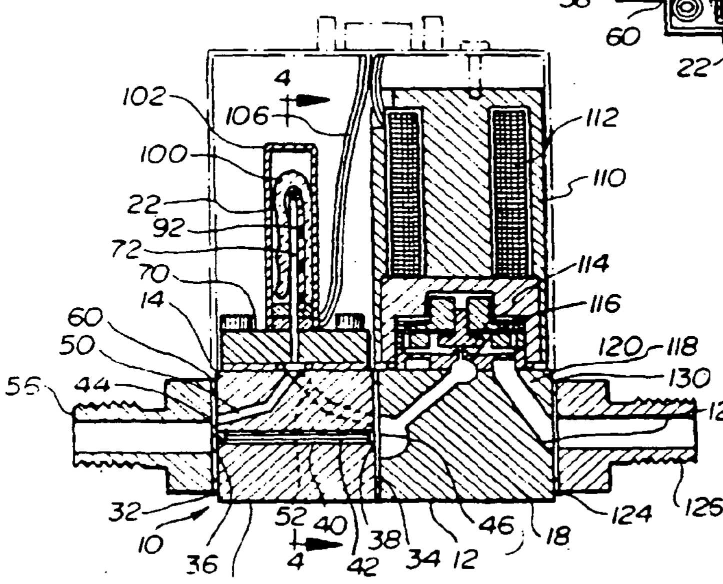


FIG.3

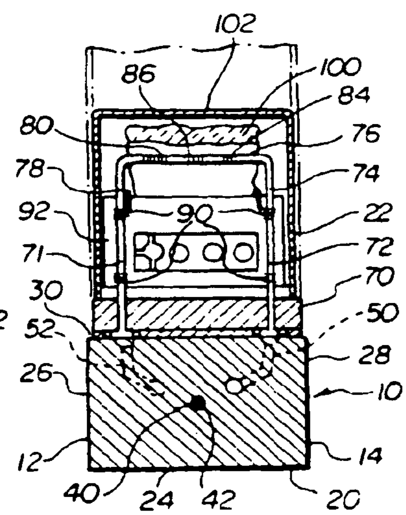


FIG 4

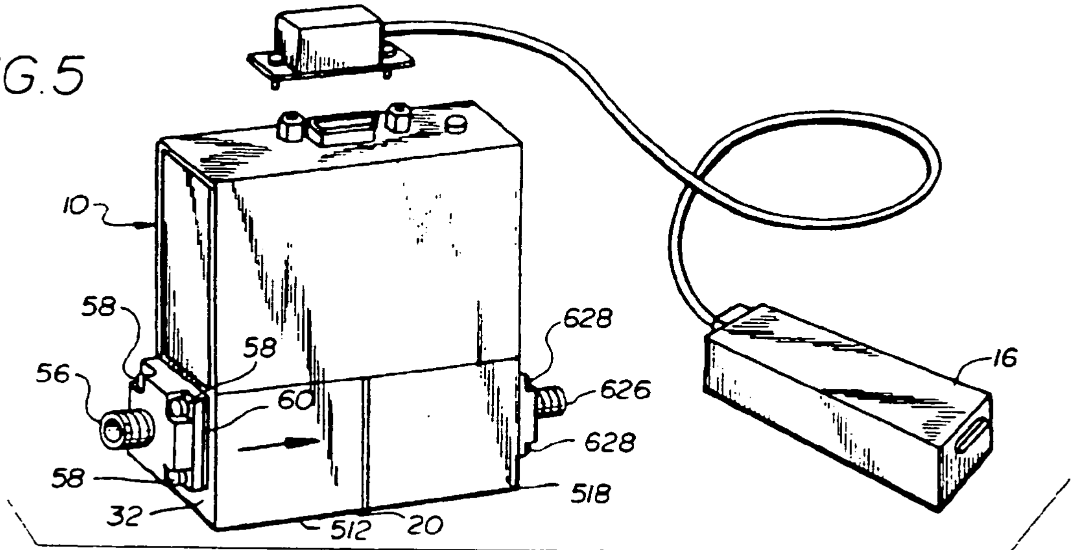


FIG.5

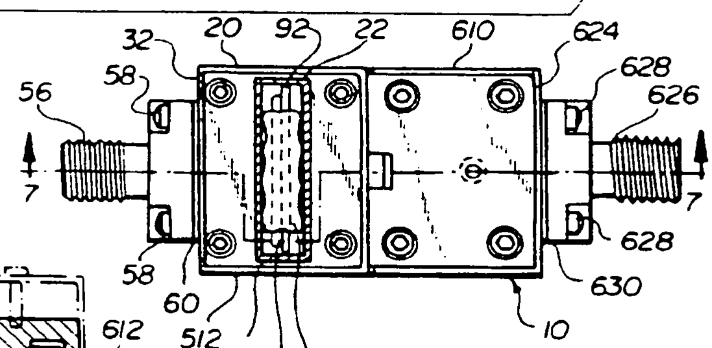


FIG.6

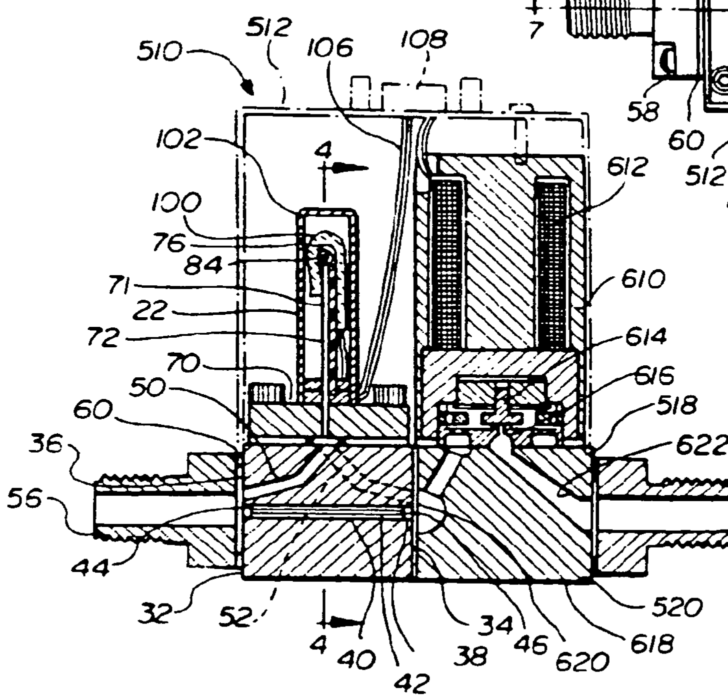


FIG.7

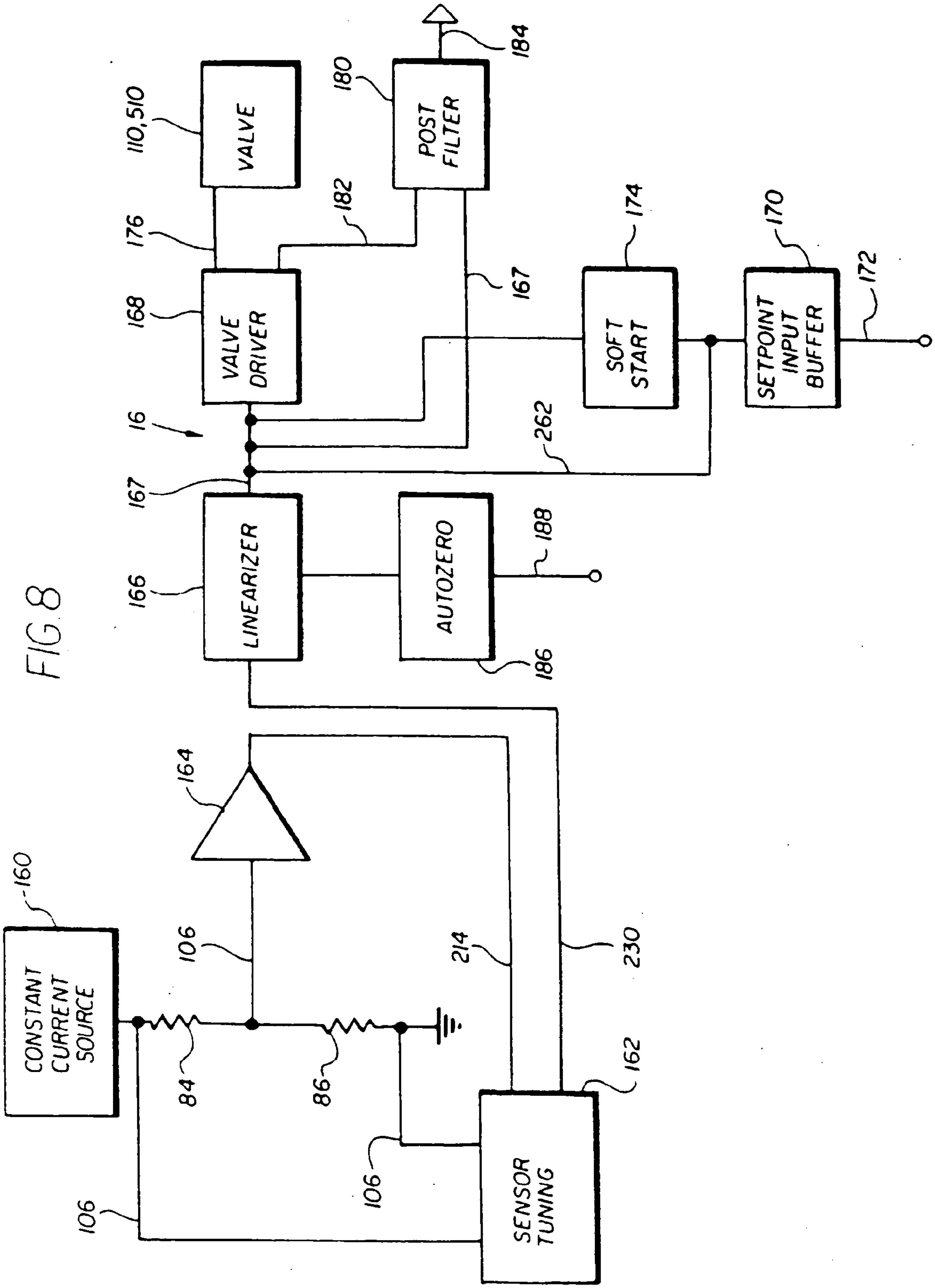

VALVE
110,510
POST FILTER
180
184
176
182
VALVE DRIVER
168
167
SOFT START
174
SETPOINT INPUT BUFFER
170
172
16
262
167
LINEARIZER
166
AUTOZERO
188
186
164
CONSTANT CURRENT SOURCE
160
106
214
230
84
86
162
106
SENSOR TUNING
106

FIG 8

FIG.9A

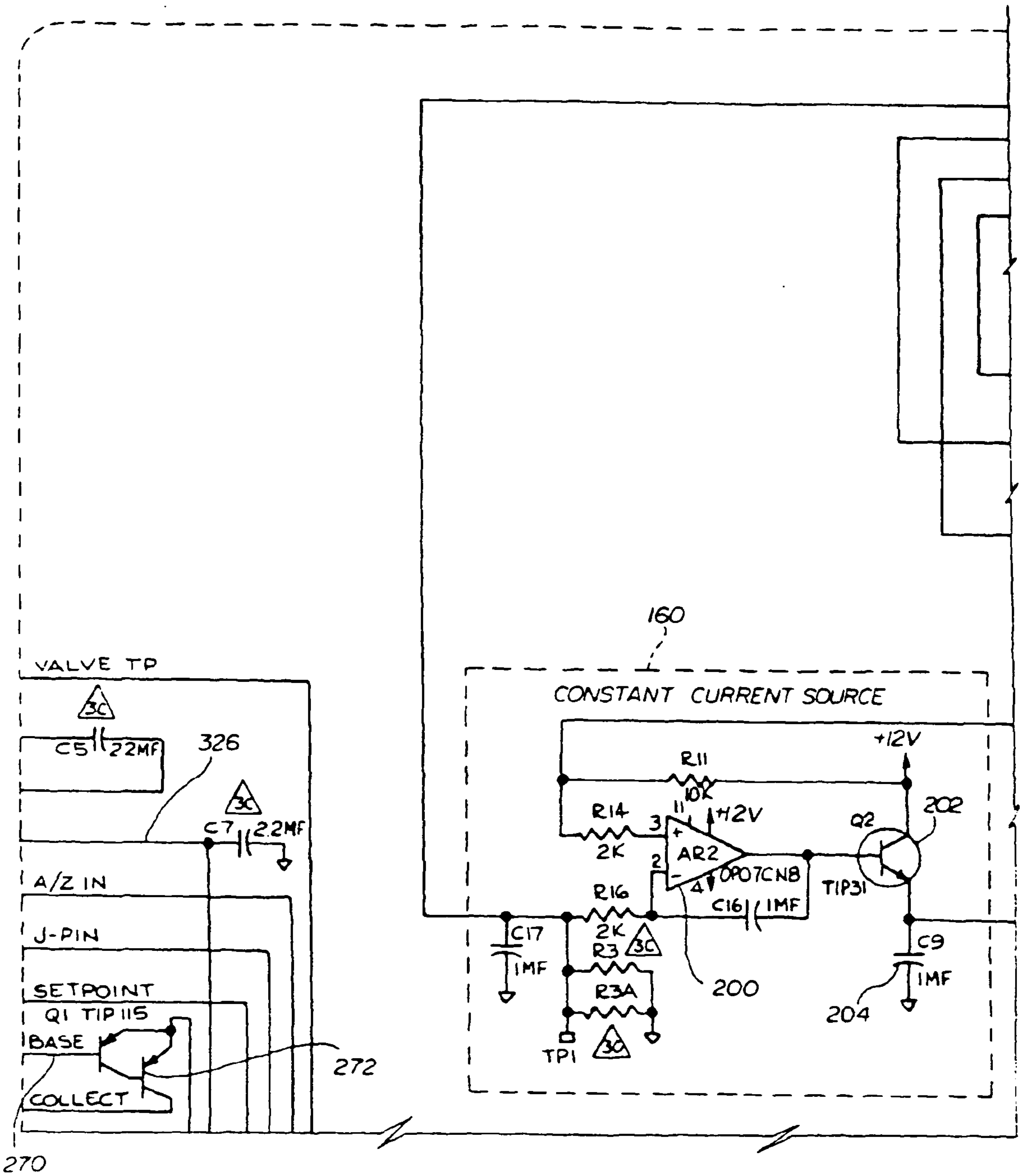

VALVE TP
3C
C5
22MF
326
3C
C7
2.2MF
A/Z IN
J-PIN
SETPOINT
Q1 TIP115
BASE
COLLECT
272
270
160
CONSTANT CURRENT SOURCE
+12V
R11
10K
R14
2K
+12V
AR2
OP07CNB
Q2
202
TIP31
R16
2K
C16
1MF
C17
1MF
R3
3C
R3A
TP1
3C
200
C9
1MF
204

FIG. 9B

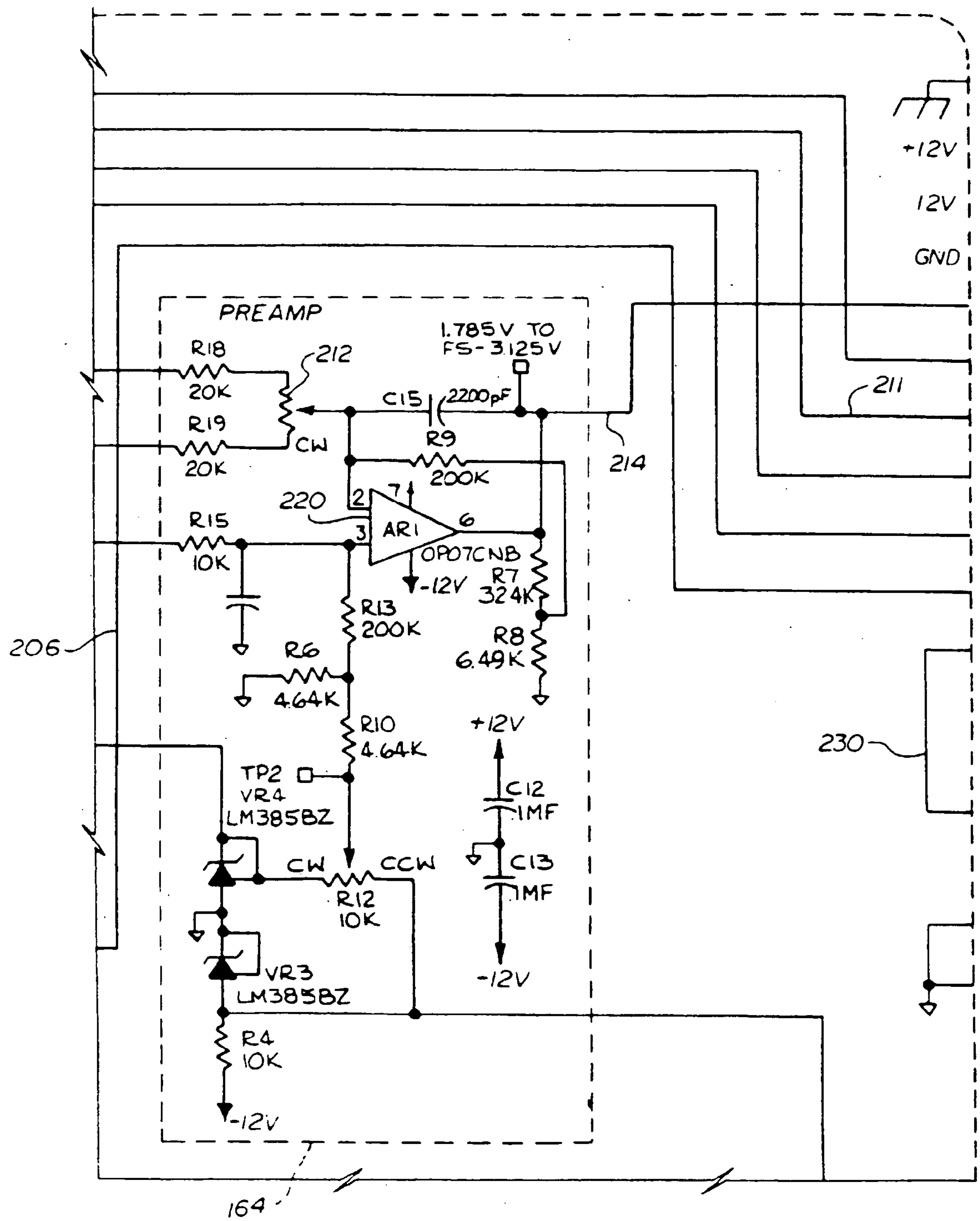

+12V
12V
GND
PREAMP
R18
20K
212
R19
20K
CW
1.785V TO
FS-3.125V
C15
2200pF
R9
200K
211
214
220
2
7
3
AR1
6
OP07CNB
-12V
R7
324K
R15
10K
R13
200K
R8
6.49K
206
R6
4.64K
R10
4.64K
+12V
230
TP2
VR4
LM385BZ
C12
.1MF
CW
CCW
C13
.1MF
R12
10K
VR3
LM385BZ
-12V
R4
10K
-12V
164

FIG 9C

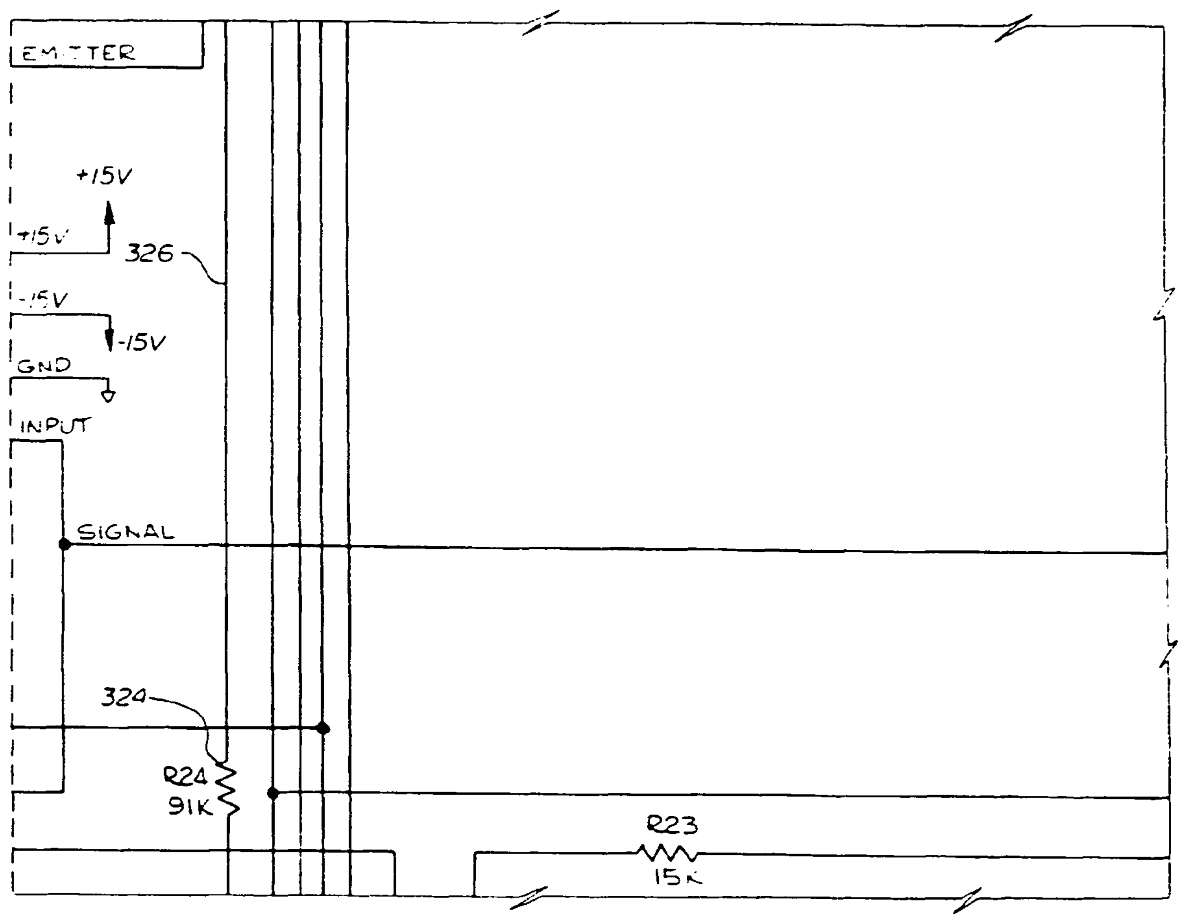

EMITTER
+15V
+15V
326
-15V
-15V
GND
INPUT
SIGNAL
324
R24
91K
R23
15K

FIG. 9D

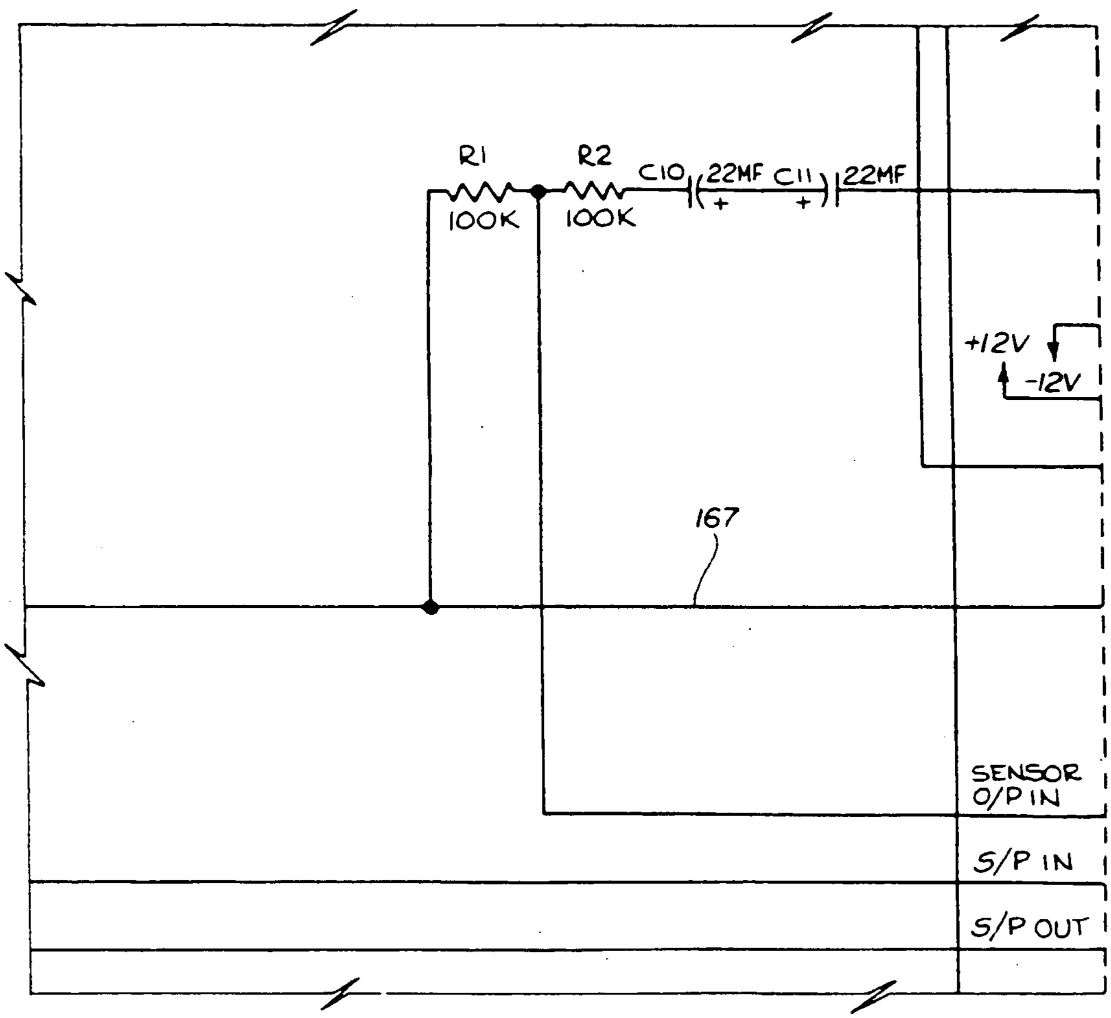

R1
100K
R2
100K
C10
22MF
C11
22MF
+
+
+12V
-12V
167
SENSOR O/P IN
S/P IN
S/P OUT

FIG 9E

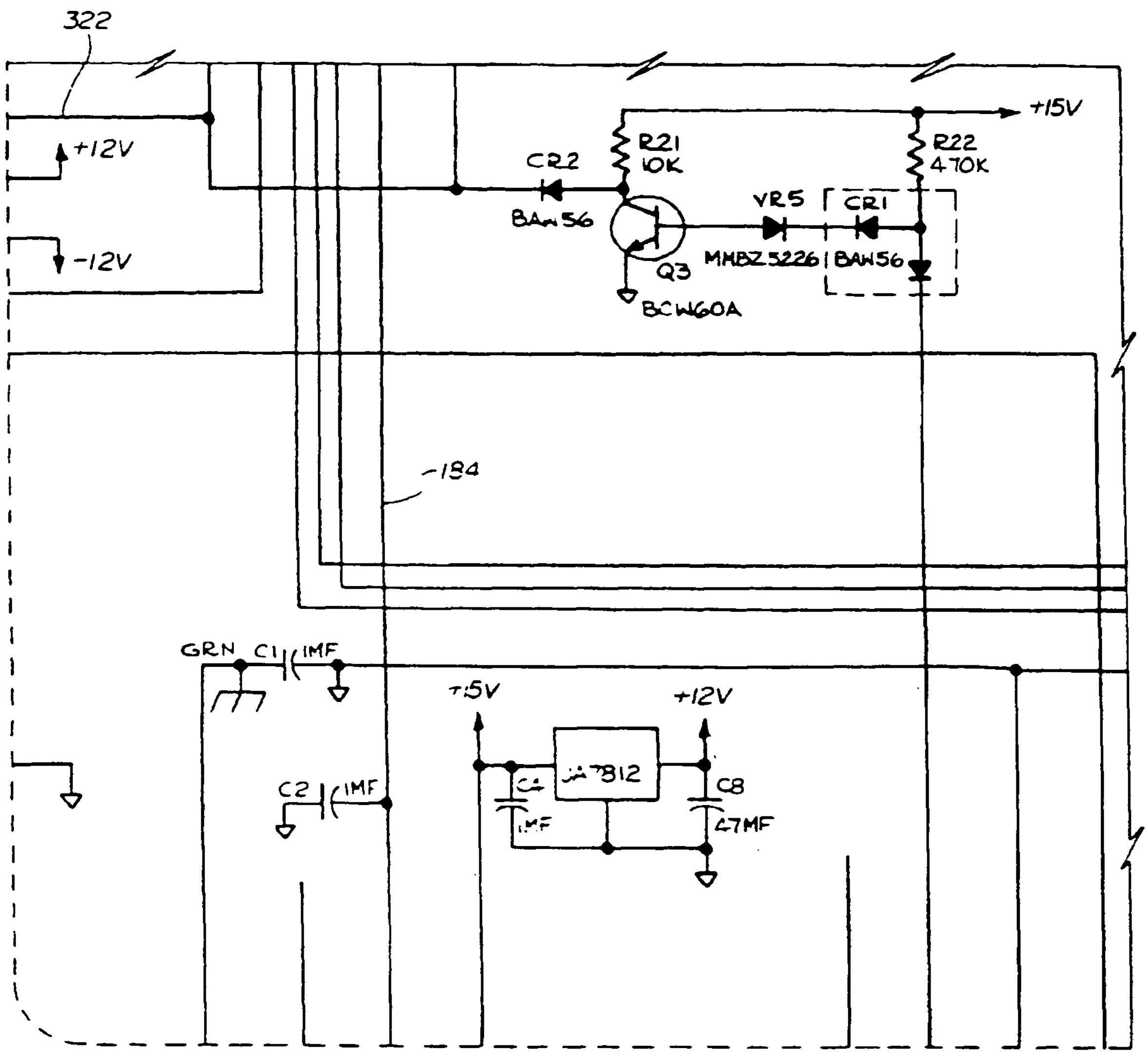

322
+12V
-12V
CR2
BAW56
R21
10K
Q3
BCW60A
VR5
MMBZ5226
CR1
BAW56
R22
470K
+15V
-184
GRN
C1
1MF
C2
1MF
+5V
+12V
C4
1MF
μA7812
C8
47MF

FIG. 9F

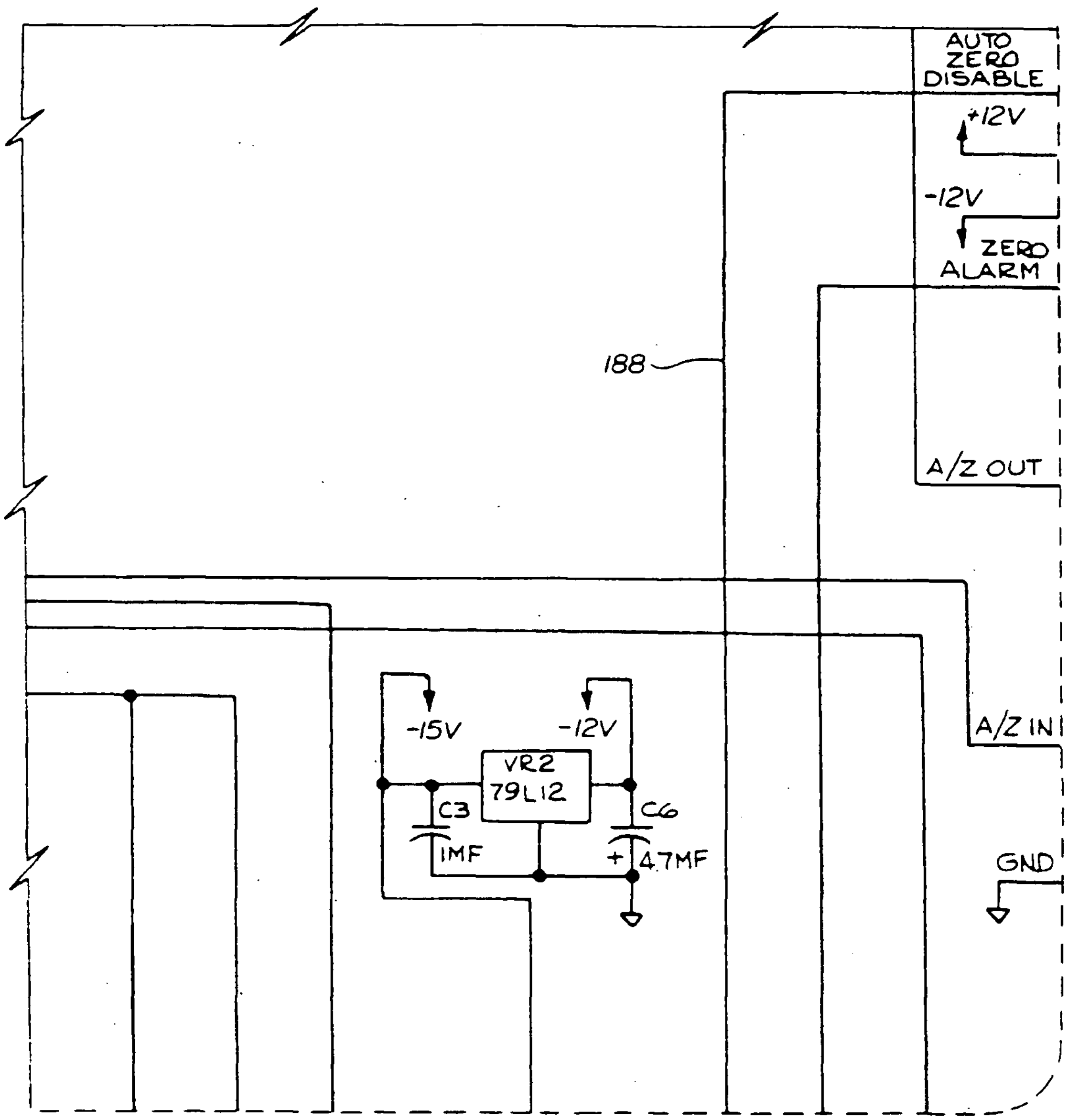

AUTO ZERO DISABLE
+12V
-12V
ZERO ALARM
188
A/Z OUT
A/Z IN
-15V
-12V
VR2
79L12
C3
1MF
C6
4.7MF
GND

FIG 10

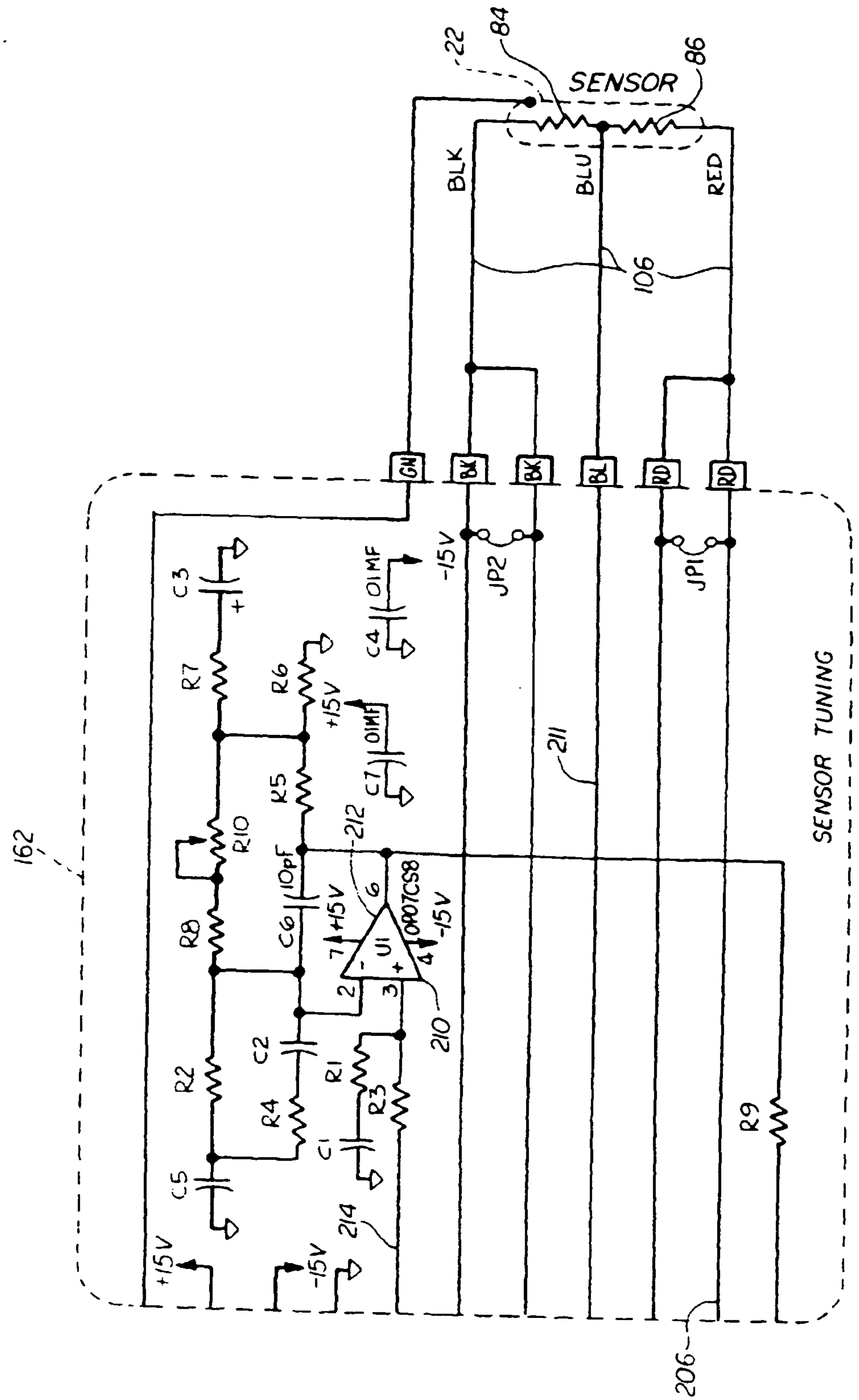

SENSOR
22
84
86
BLK
BLU
RED
106
GN
BK
BK
BL
RD
RD
JP2
JP1
-15V
C4
.01MF
C3
R7
R6
+15V
.01MF
C7
R5
R10
10pf
212
211
C6
R8
+15V
-15V
U1
OP07CS8
2
3
4
6
7
210
C2
R2
R1
R3
R4
C1
C5
214
+15V
-15V
R9
206
SENSOR TUNING
162

FIG. 11

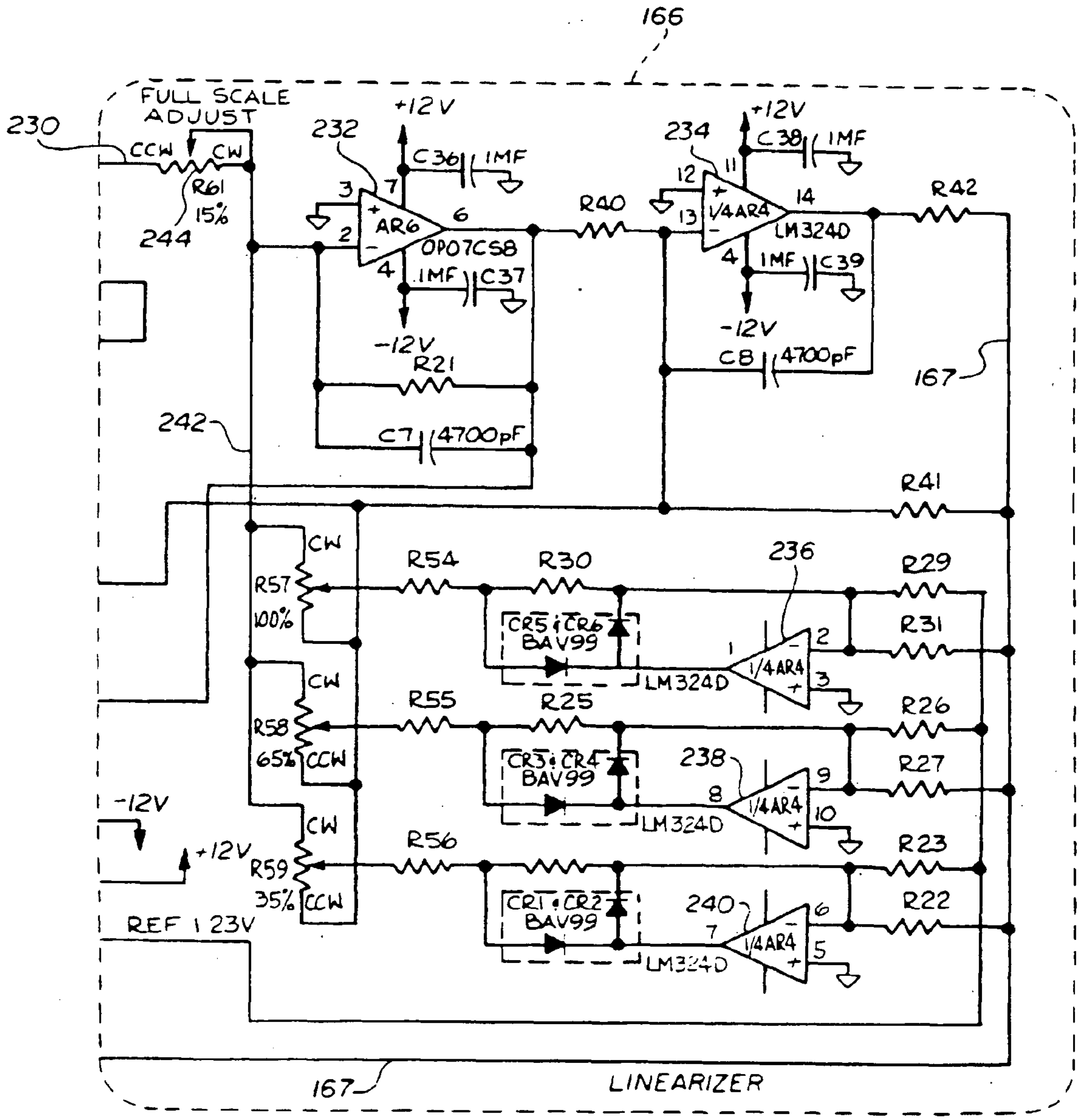

166
FULL SCALE ADJUST
230
CCW
CW
R61
15%
244
232
+12V
C36
1MF
3
7
AR6
6
2
4
OP07CS8
1MF
C37
-12V
R21
C7
4700pF
R40
234
+12V
C38
1MF
12
11
13
1/4AR4
14
LM324D
R42
4
1MF
C39
-12V
C8
4700pF
167
242
R41
CW
R54
R30
236
R29
R57
100%
CR5 & CR6
BAV99
1
1/4AR4
2
R31
LM324D
3
CW
R55
R25
R26
R58
65%
CCW
CR3 & CR4
BAV99
238
9
R27
8
1/4AR4
10
LM324D
-12V
CW
R56
R23
+12V
R59
35%
CCW
CR1 & CR2
BAV99
240
6
R22
7
1/4AR4
5
REF 1.23V
LM324D
167
LINEARIZER

FIG. 12A

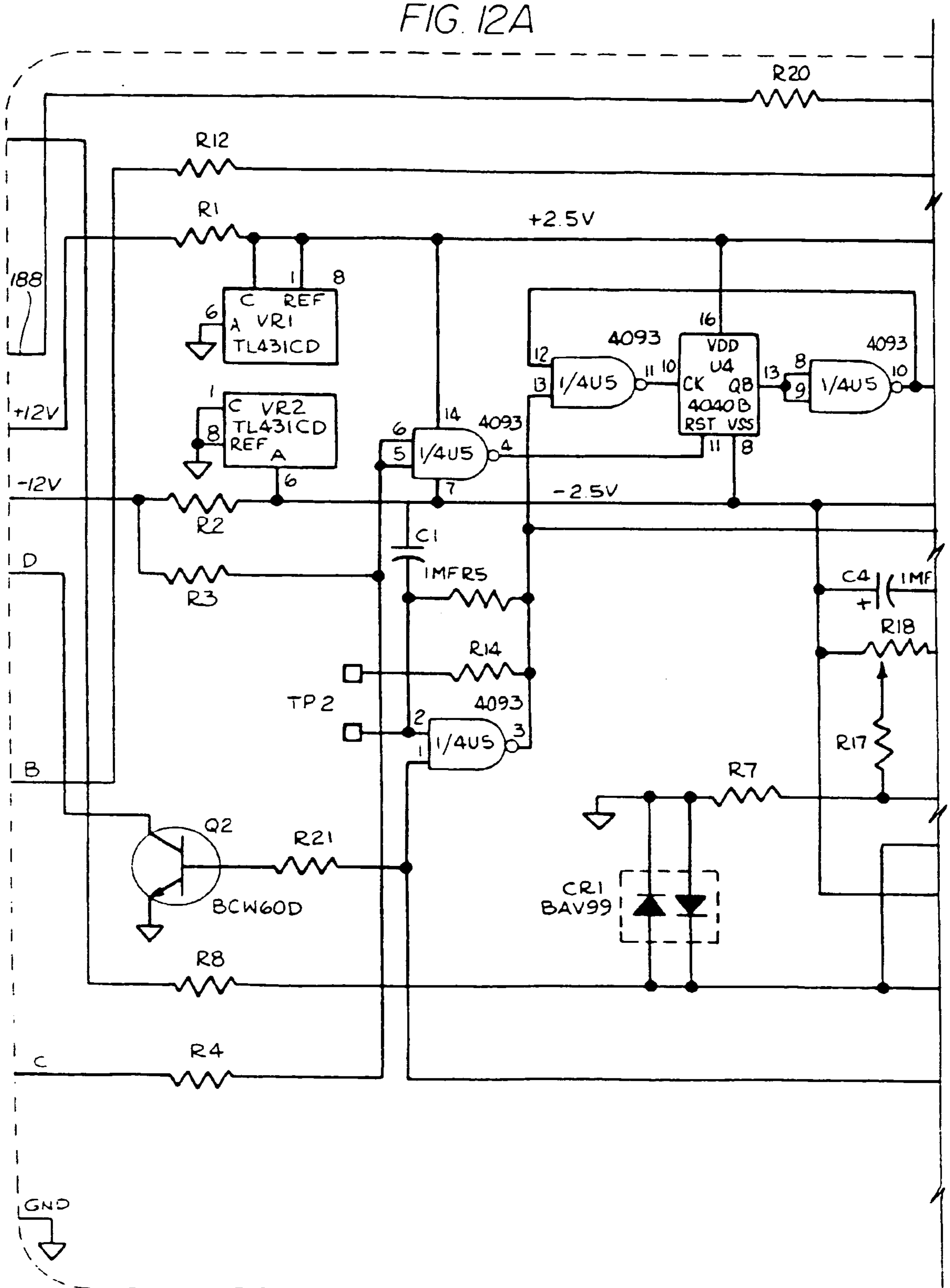

R20
R12
R1
+2.5V
188
C REF
VR1
TL431CD
C VR2
TL431CD
REF
+12V
-12V
4093
1/4US
VDD
U4
CK QB
4040B
RST VSS
-2.5V
R2
R3
C1
1MF R5
R14
TP2
C4
1MF
R18
R17
R7
CR1
BAV99
D
B
Q2
BCW60D
R21
R8
R4
C
GND

FIG. 12B

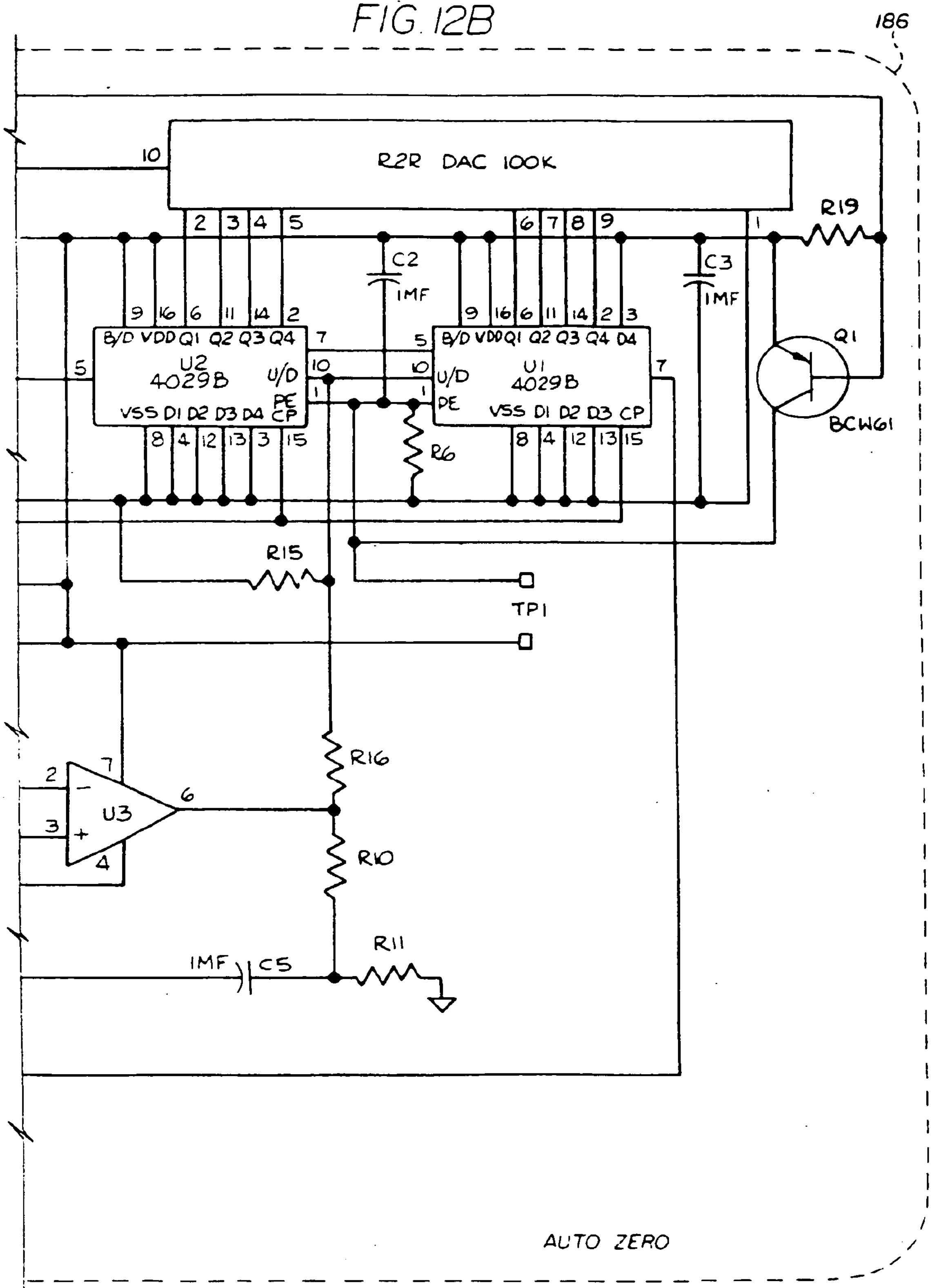

186
R2R DAC 100K
10
2
3
4
5
6
7
8
9
1
R19
C2
1MF
C3
1MF
B/D VDD Q1 Q2 Q3 Q4
U2
4029B
U/D
PE
CP
VSS D1 D2 D3 D4
B/D VDD Q1 Q2 Q3 Q4 D4
U1
4029B
U/D
PE
VSS D1 D2 D3 CP
Q1
BCW61
R6
R15
TP1
U3
R16
R10
R11
1MF
C5
AUTO ZERO

FIG.13A

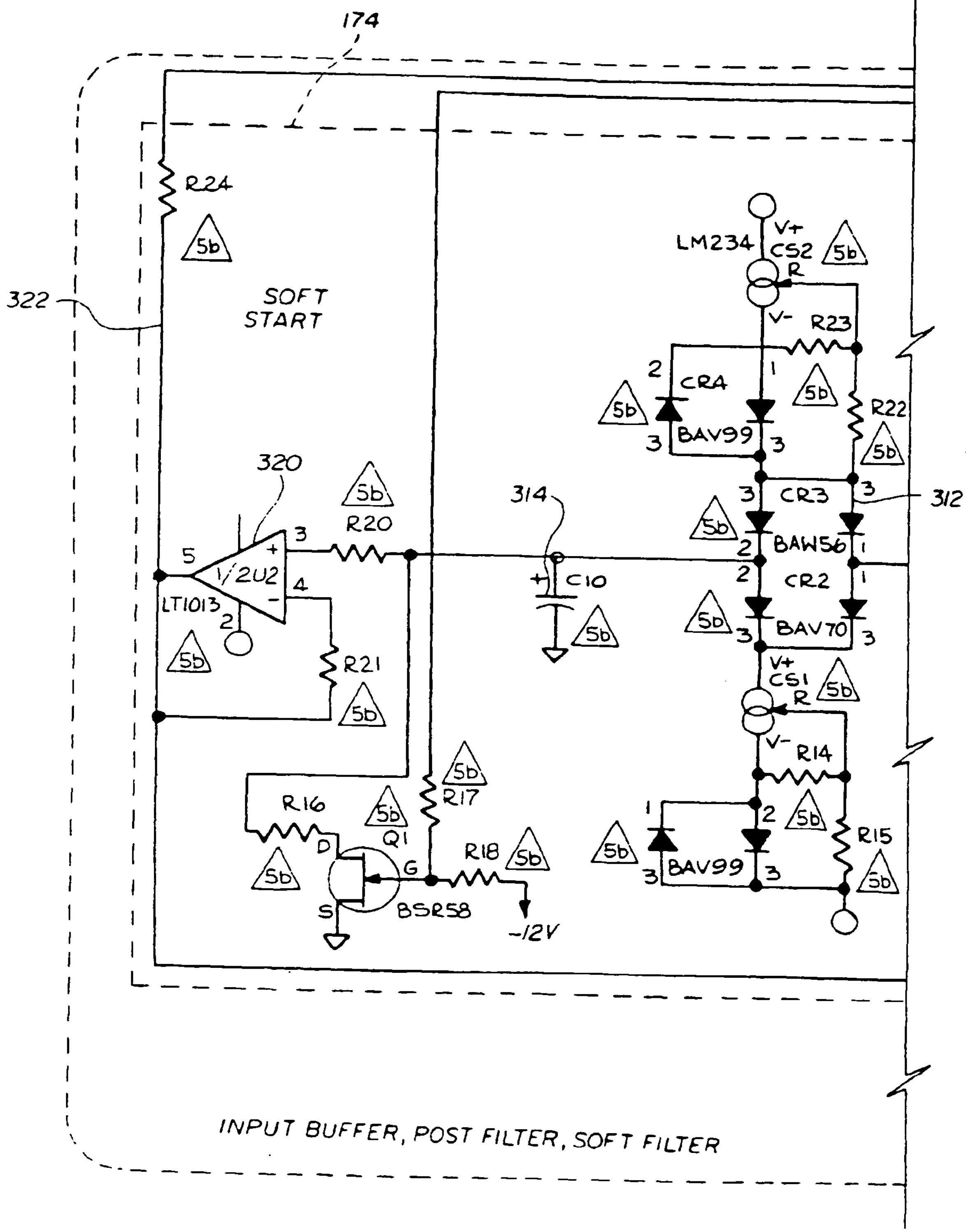

174
322
SOFT START
R24
5b
320
5
1/2U2
LT1013
3
4
2
R20
R21
314
C10
LM234
V+
CS2
R
V-
R23
CR4
BAV99
R22
CR3
BAW56
312
CR2
BAV70
CS1
R14
R15
R16
Q1
D
G
S
BSR58
R17
R18
-12V
INPUT BUFFER, POST FILTER, SOFT FILTER

FIG. 13B

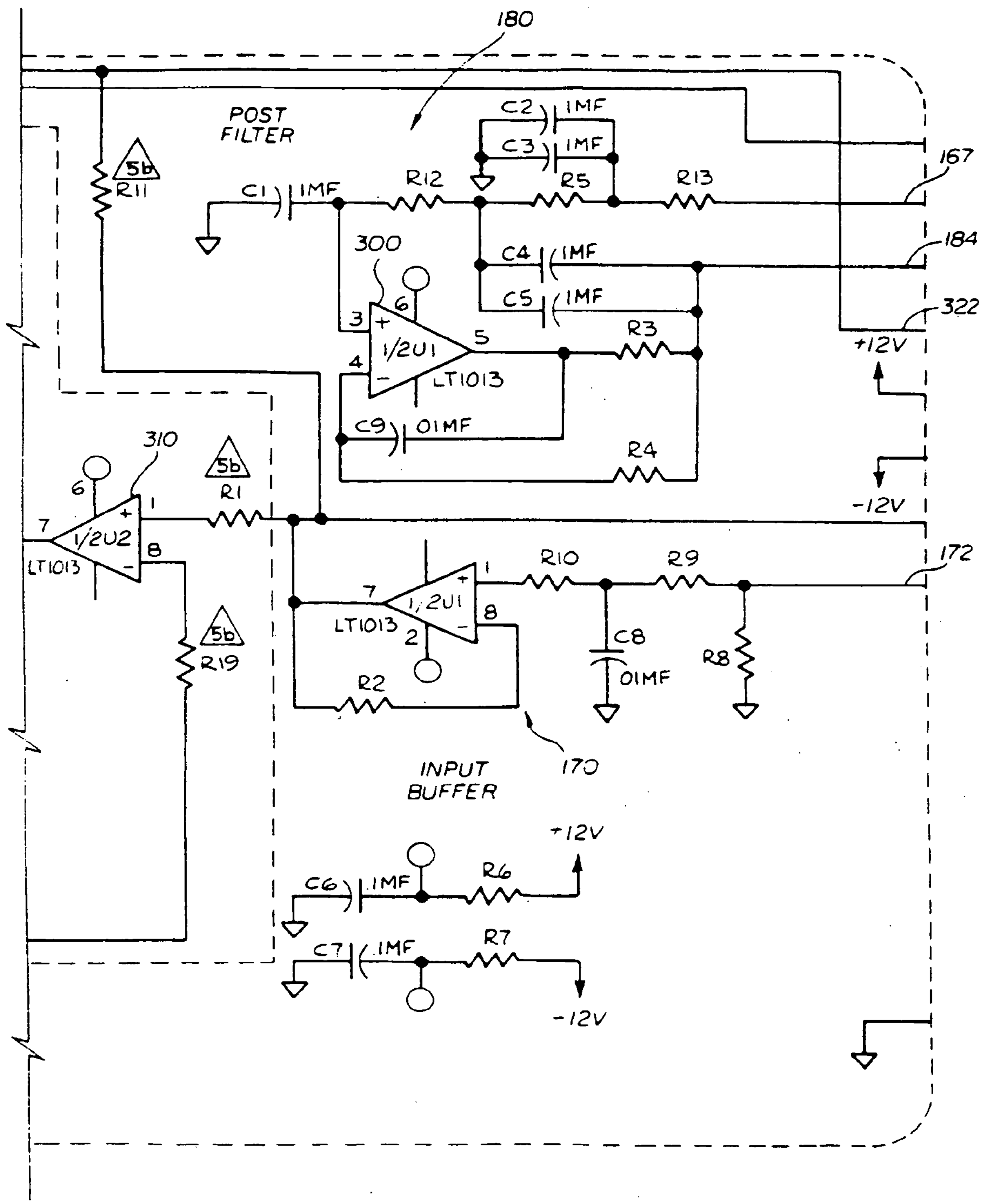

180
POST FILTER
5b
R11
C1
.1MF
R12
C2
.1MF
C3
.1MF
R5
R13
167
300
C4
.1MF
184
C5
.1MF
322
6
3
5
1/2U1
R3
+12V
4
LT1013
C9
.01MF
R4
-12V
310
5b
6
R1
1
7
1/2U2
LT1013
8
R10
R9
172
7
1/2U1
LT1013
8
2
C8
.01MF
R8
5b
R19
R2
170
INPUT BUFFER
+12V
C6
.1MF
R6
C7
.1MF
R7
-12V

FIG.14A

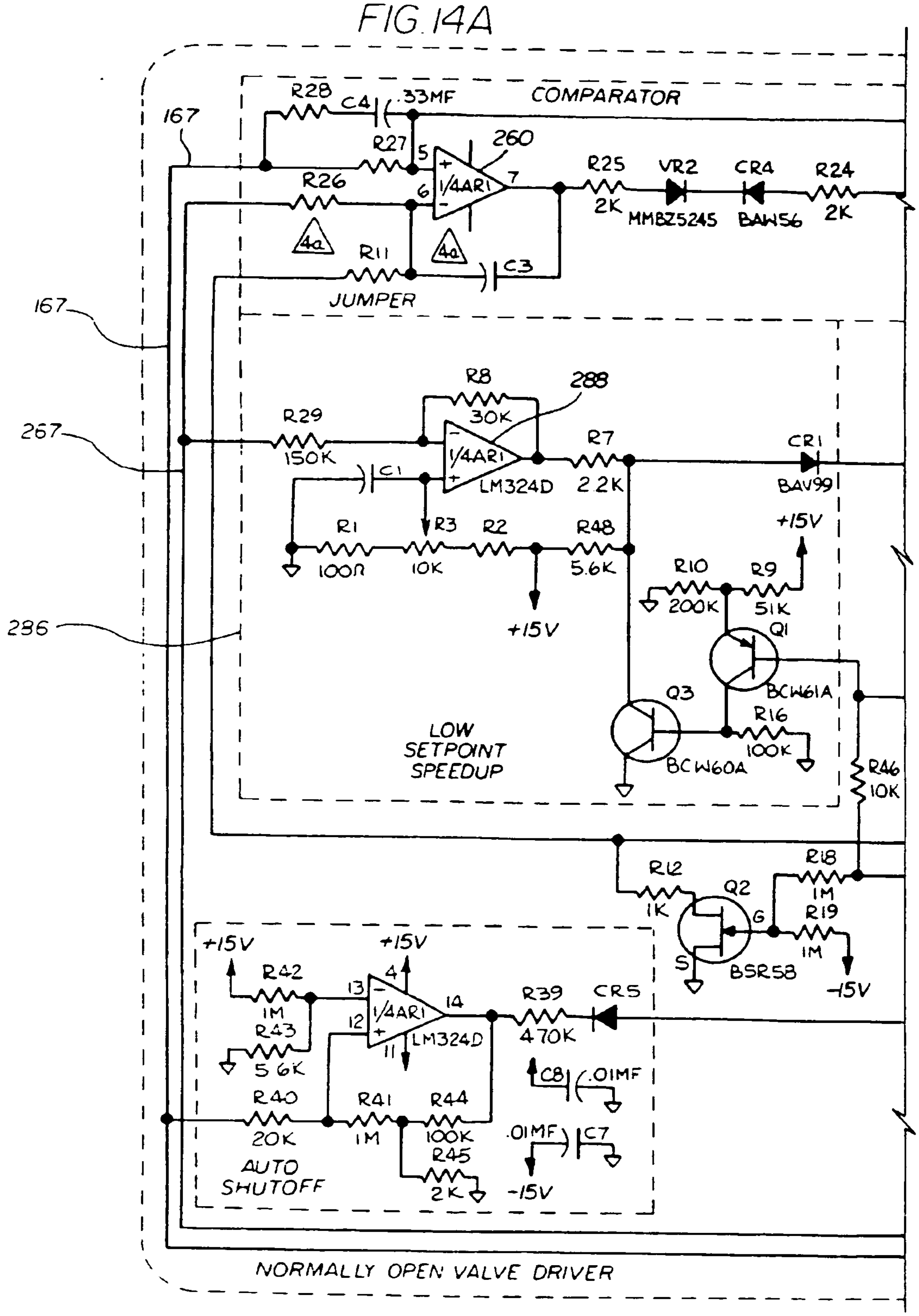

COMPARATOR
R28
C4
.33MF
167
R27
5
260
R26
6
1/4AR1
7
R25
2K
VR2
MMBZ5245
CR4
BAW56
R24
2K
4a
4a
R11
C3
JUMPER
167
R8
30K
288
R29
150K
267
1/4AR1
LM324D
R7
2.2K
CR1
BAV99
C1
R1
100Ω
R3
10K
R2
R48
5.6K
+15V
+15V
R10
200K
R9
51K
286
Q1
BCW61A
Q3
BCW60A
R16
100K
LOW
SETPOINT
SPEEDUP
R46
10K
R12
1K
Q2
G
S
BSR58
R18
1M
R19
1M
-15V
+15V
+15V
R42
1M
4
13
12
1/4AR1
LM324D
14
11
R43
5.6K
R39
470K
CR5
C8
.01MF
R40
20K
R41
1M
R44
100K
R45
2K
.01MF
C7
-15V
AUTO
SHUTOFF
NORMALLY OPEN VALVE DRIVER

FIG. 14B

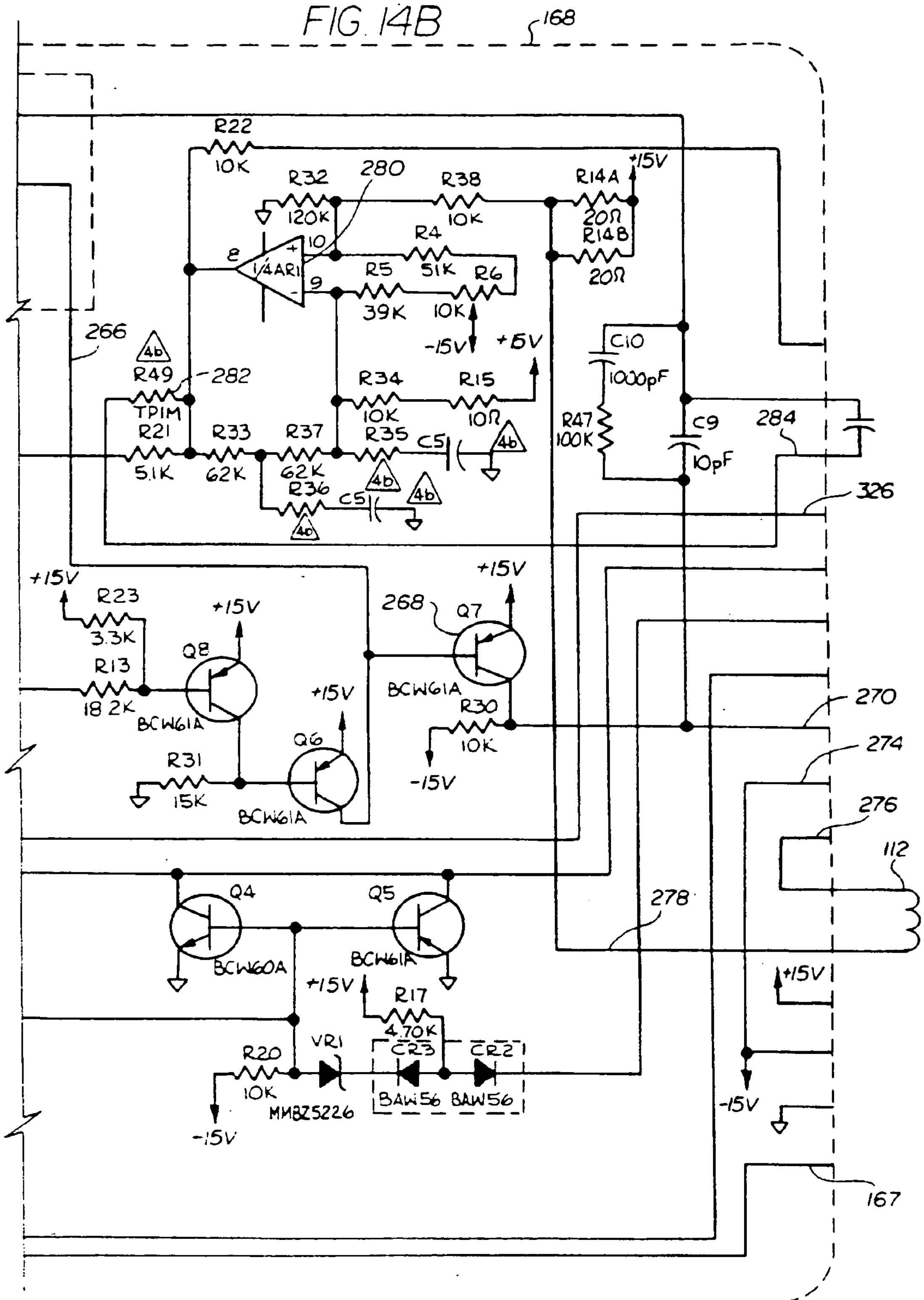

168
R22
10K
R32
280
R38
R14A
+15V
120K
10K
20Ω
R14B
R4
8
10
1/4AR1
R5
51K
R6
9
39K
10K
20Ω
-15V
+15V
266
4b
R49
282
TPIM
R21
R34
R15
10K
10Ω
R33
R37
R35
C5
5.1K
62K
62K
R36
C5
C10
1000pF
R47
100K
C9
10pF
284
326
+15V
R23
3.3K
R13
18.2K
Q8
BCW61A
+15V
268
Q7
BCW61A
R30
10K
-15V
R31
15K
Q6
BCW61A
270
274
276
112
Q4
Q5
BCW60A
BCW61A
278
+15V
R17
4.70K
R20
10K
VR1
MMBZ5226
CR3
CR2
BAW56
BAW56
-15V
-15V
167

FIG.15A

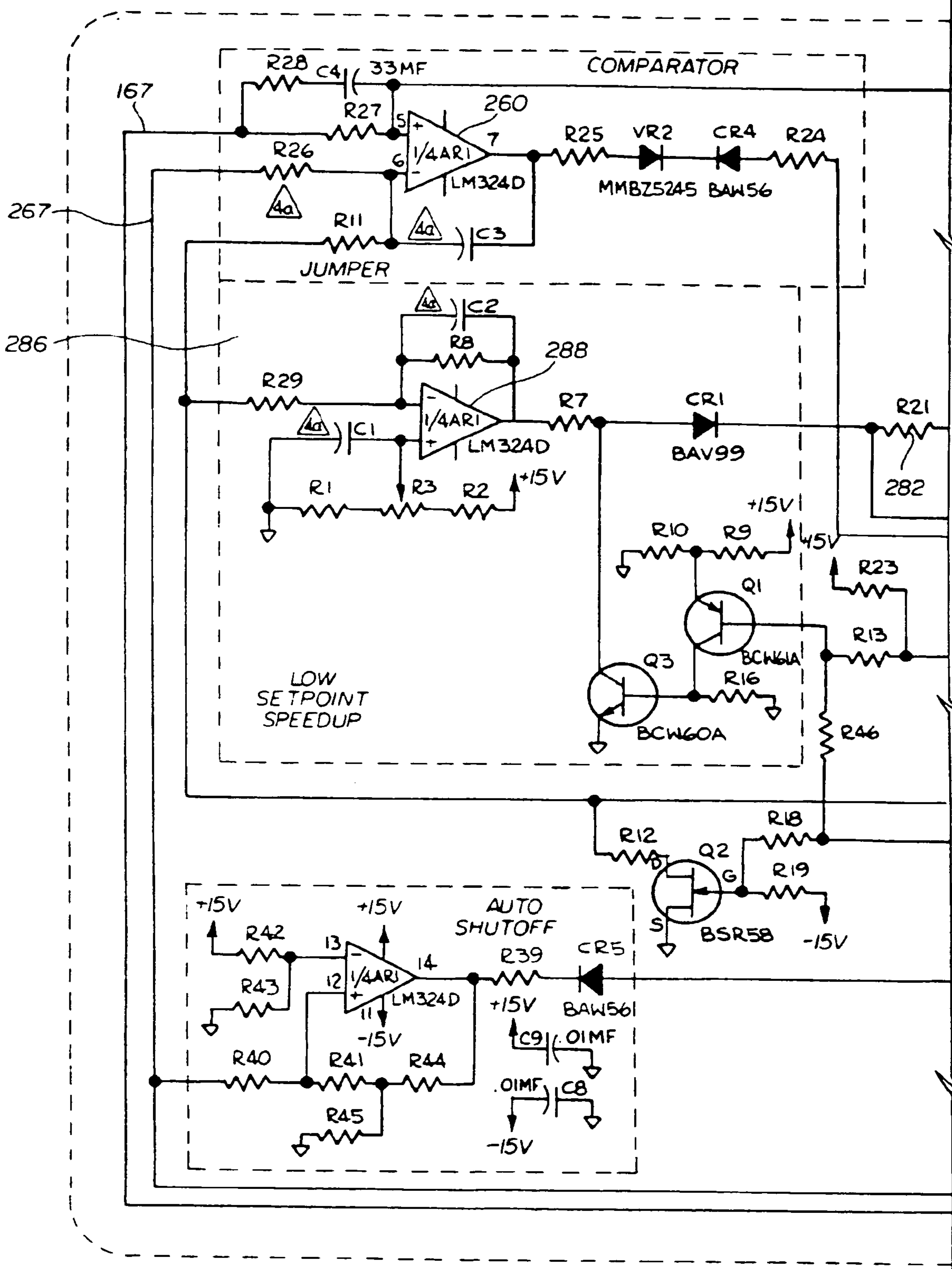

167
R28
C4
33MF
COMPARATOR
R27
260
5
7
1/4AR1
LM324D
6
R26
4a
R11
4a
C3
JUMPER
R25
VR2
CR4
R24
MMBZ5245
BAW56
267
286
4a
C2
R8
288
R29
1/4AR1
LM324D
4a
C1
R7
CR1
BAV99
R21
282
R1
R3
R2
+15V
+15V
R10
R9
45V
R23
Q1
BCW61A
R13
Q3
R16
LOW
SETPOINT
SPEEDUP
BCW60A
R46
R12
R18
Q2
D
G
R19
S
BSR58
-15V
+15V
R42
13
+15V
AUTO
SHUTOFF
14
R39
CR5
R43
12
1/4AR1
LM324D
11
+15V
BAW56
C9
.01MF
-15V
R40
R41
R44
.01MF
C8
R45
-15V

FIG. 15B

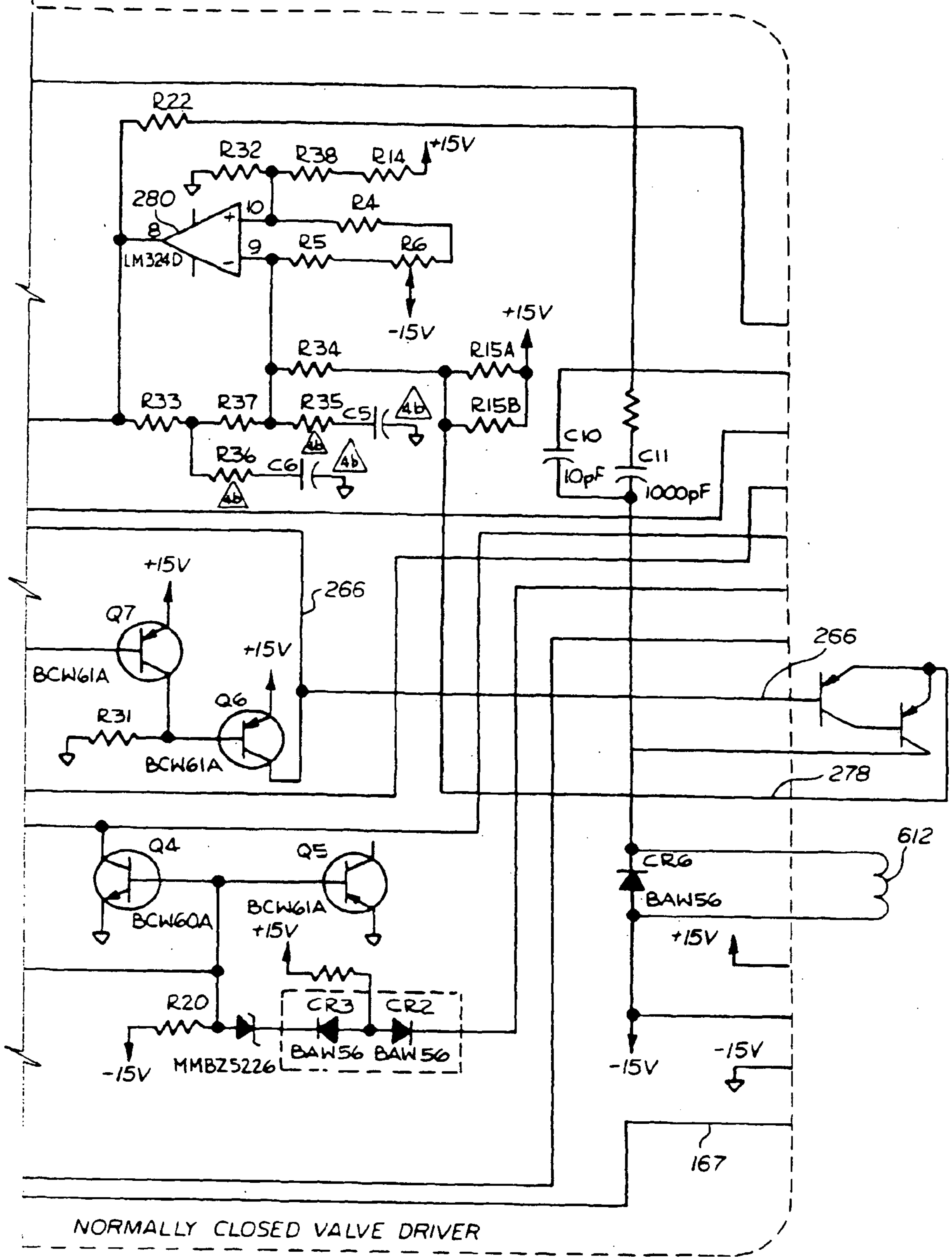
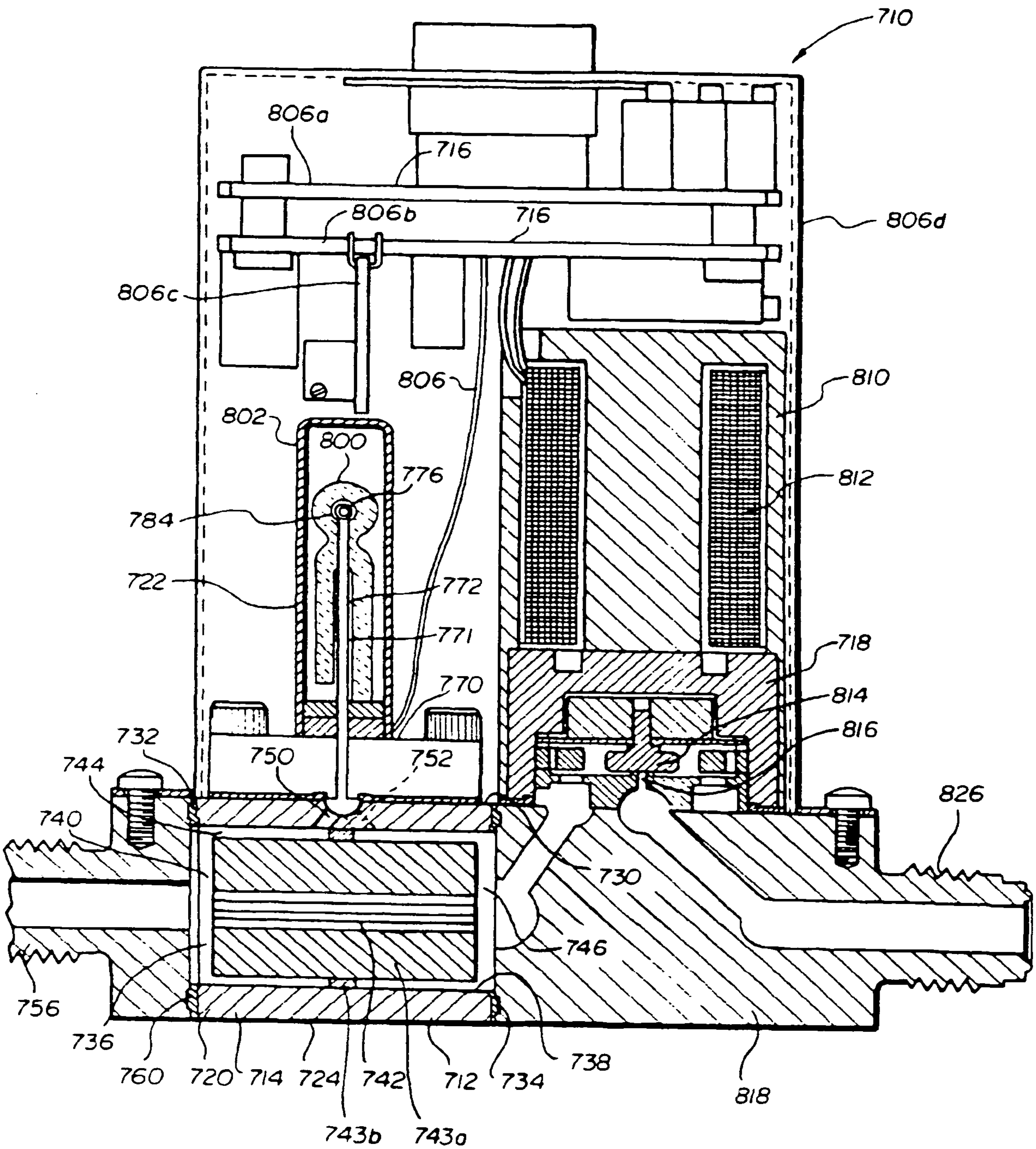

R22
R32
R38
R14
+15V
280
10
R4
8
9
R5
R6
LM324D
-15V
+15V
R34
R15A
R33
R37
R35
C5
4b
R15B
R36
C6
C10
10pF
C11
1000pF
+15V
266
Q7
+15V
BCW61A
Q6
R31
BCW61A
266
278
Q4
Q5
612
CR6
BCW61A
BAW56
BCW60A
+15V
+15V
R20
CR3
CR2
BAW56
BAW56
-15V
MMBZ5226
-15V
-15V
167
NORMALLY CLOSED VALVE DRIVER

FIG.16


710
806a
716
806b
716
806d
806c
806
810
802
800
776
812
784
722
772
771
718
770
814
732
816
750
752
744
826
740
730
746
756
736
760
720
714
724
742
712
734
738
818
743b
743a

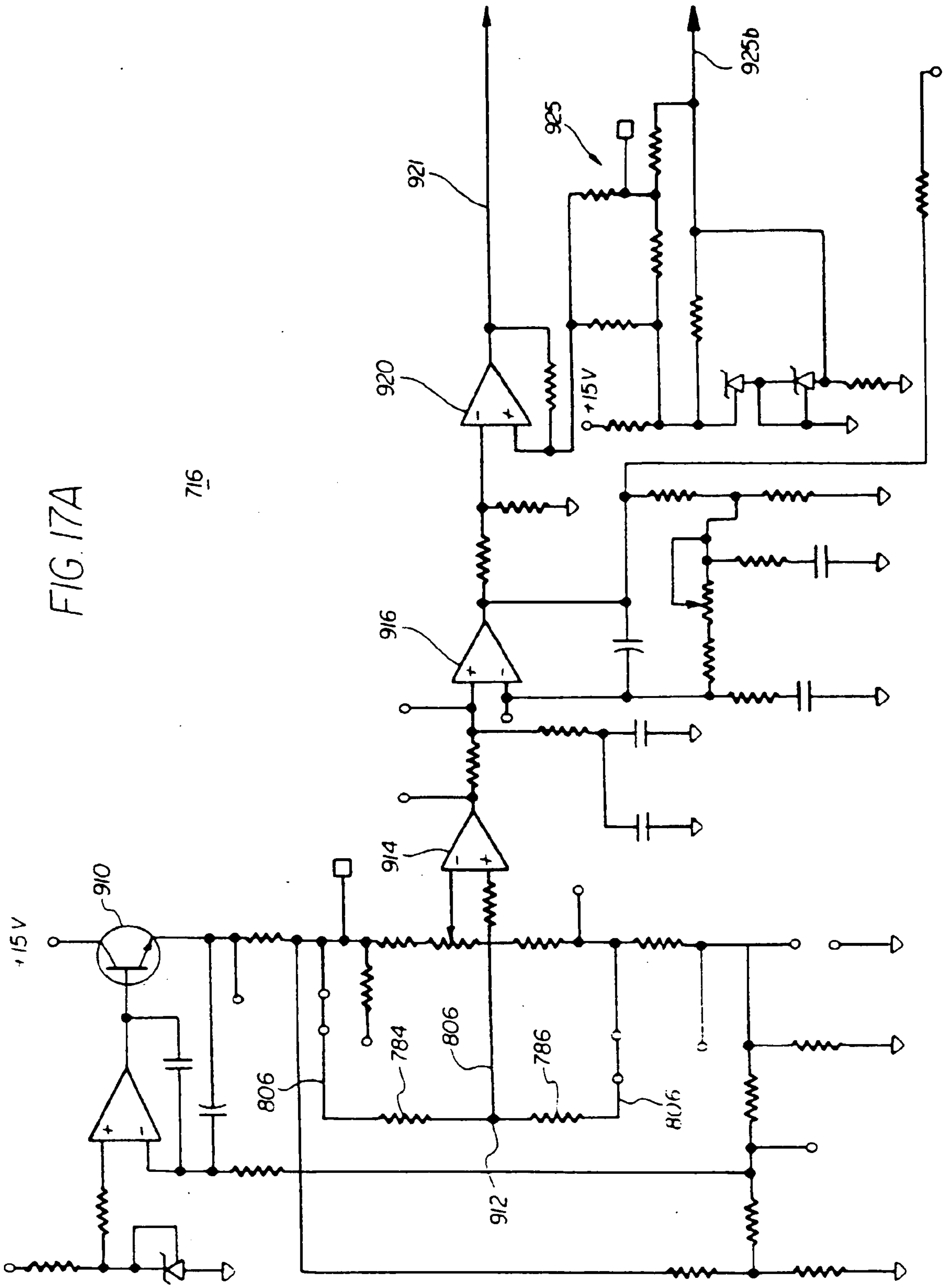


FIG.17A

FIG 17B

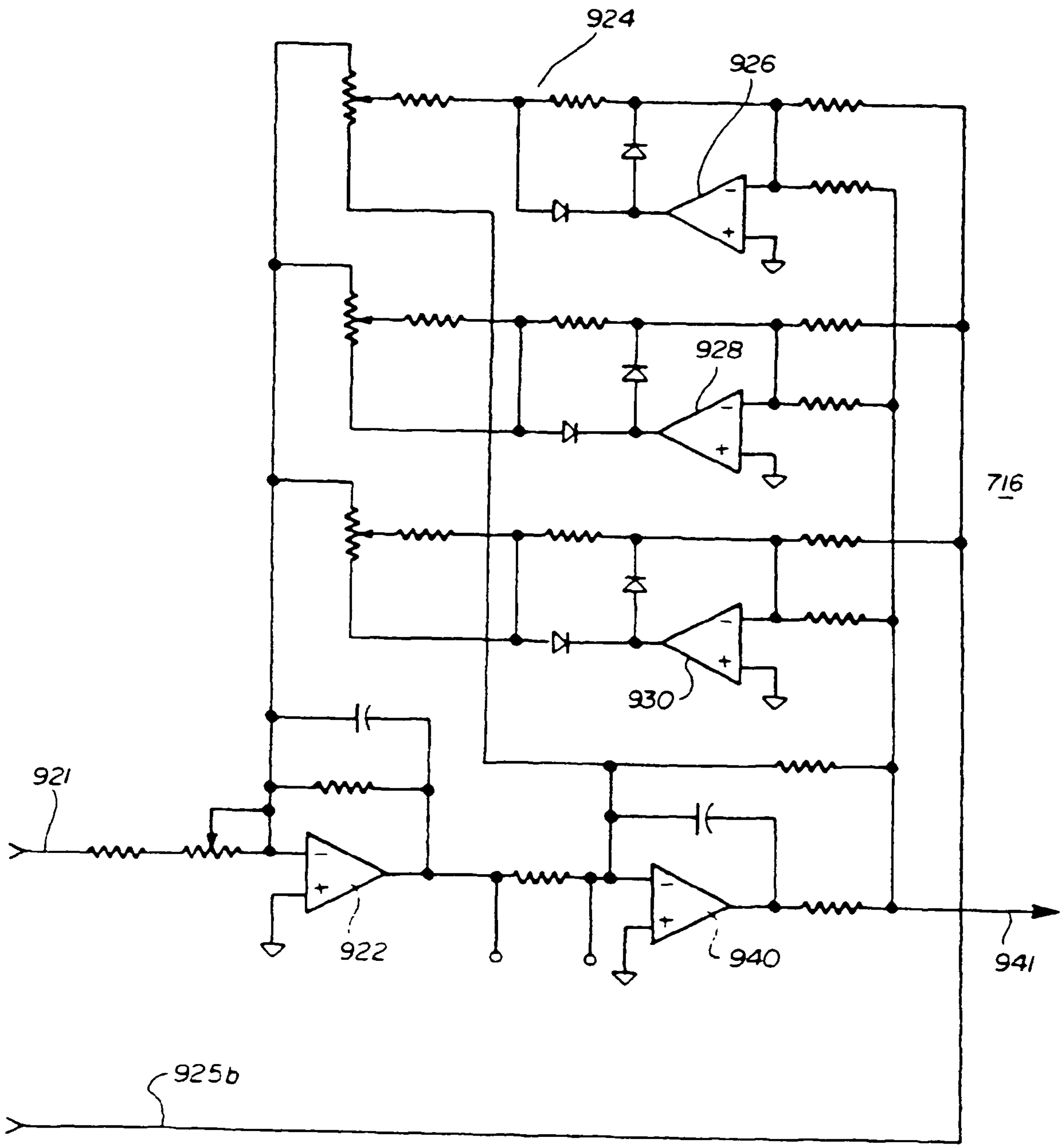
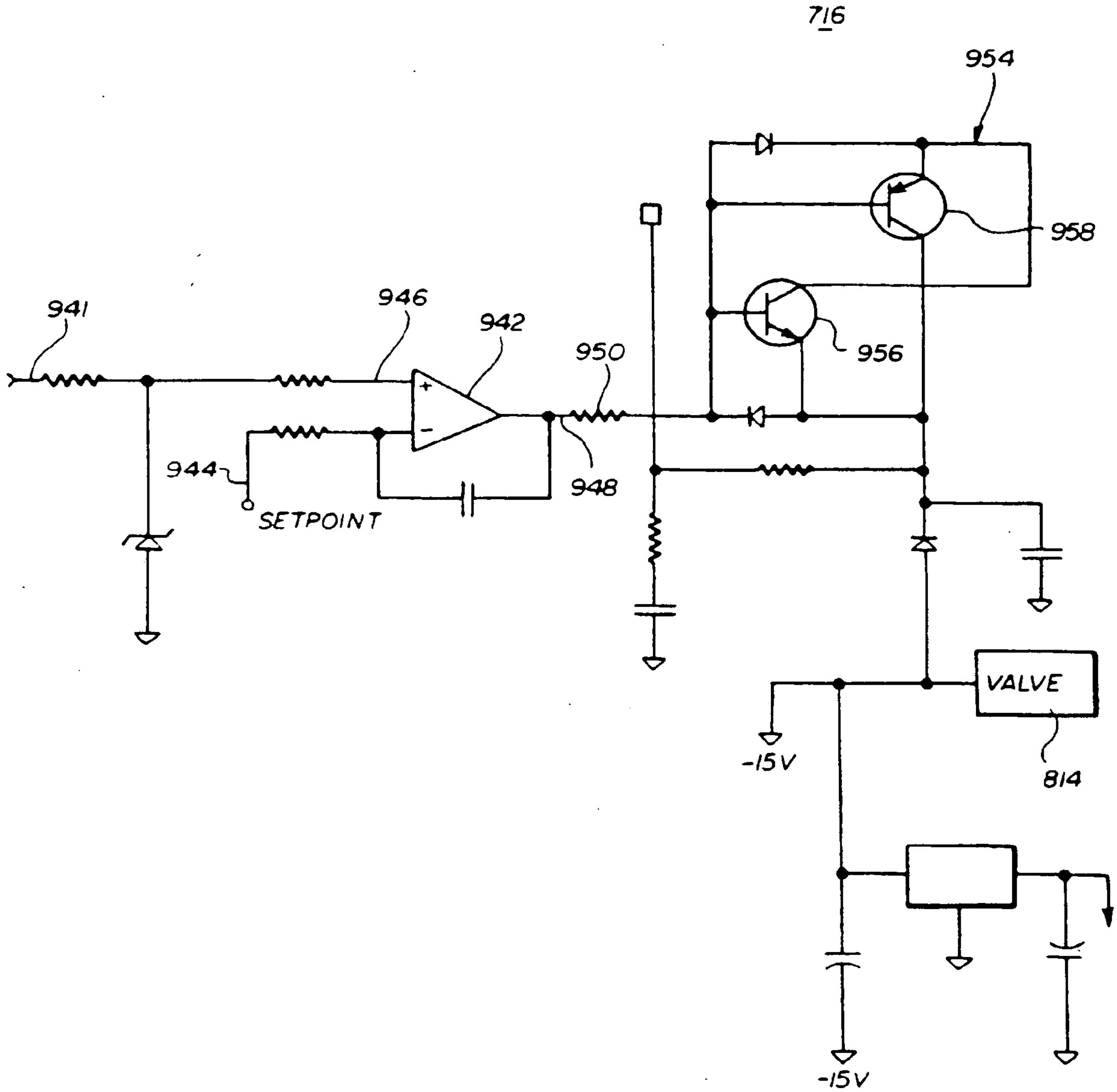


FIG.17C


716
954
958
956
941
946
942
950
944
SETPOINT
948
VALVE
-15V
814
-15V